Development of improved gasifier based Italian (Sidlaghatta cottage basin) oven

Prepared for Swiss Agency for Development and Cooperation (SDC),
Bangalore

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1

Introduction

Background: summary of earlier projects

After successfully developing gasifier-based systems for cottage basin silk reeling as well as dyeing ovens in the earlier projects sponsored by SDC under its SERI-2000 programme, as an extension of the activity in the silk reeling industry, it was decided to develop a gasifier-based system for Italian (Sidlaghatta cottage-basin) oven. The Sidlaghatta cluster is considered to produce the best quality silk yarn in Karnataka on account of certain special characteristics such as stiffness, lower sericin content etc. and therefore silk fetches higher premium price in the market. The process of cocoon cooking and silk yarn reeling as well as layout of the unit is quite different here from that adopted in other silk reeling clusters of southern India.

Survey was carried out in about 60 Italian basin ovens. Detailed energy audit was carried out in selected units to understand the specific process requirements and the present energy use pattern in order to obtain base data to design suitable gasifier system. Considering the field conditions/limitations (frequent power cuts, small capacity - 4 reeling basin user) it was decided to develop an updraft gasifier design. The major advantages of an updraft gasifier design include:

- ability to accept relatively larger size cutwood pieces (less fuelwood cutting requirement) and
- requirement of relatively low power blower for its operation (can even be operated on natural draft mode without necessity of having electrical backup).

The prototype unit was installed at two units in Sidlaghatta for long duration field-testing and to collect comparative performance data in order to quantify benefits of gasifier based system vis-à-vis traditional system.

After completion of long duration field testing a project-cum-design review workshop was organized on 12th June 2001 at Sidlaghatta. Several reelers (including users of gasifier system), officials from various organizations such as DoS-Karnataka, KSSRDI, SDC, TERI participated in this workshop. Everyone appreciated the performance and usefulness of the gasifier system. Several suggestions came forward during the discussions to improve the system so as to make it acceptable and marketable. The main concern of the reeler's was either to get sufficient charcoal or some alternative arrangement for drying silk yarn during reeling process.

Objectives

The main objective of this phase of the project was to improve the system design based on the feedback received during the design review workshop so that it can meet the reeler's requirements and thus result in a more user-friendly, acceptable marketable product. The major objectives of the proposed phase of the project are:

- Improvising the system design (modifications in present retrofitting gasifier option) based on feedback received during the project review workshop of the earlier project phase.
- Field testing of the improved prototype design under performance evaluation
- Documenting the findings of the project phase in the form of reports etc.

Following are the list of activities listed in the original project proposal (Annexure 1) submitted in order to achieve these project objectives:

1. Formation of project co-ordination committee
2. Organization of project co-ordination committee meetings
3. Development and testing of charcoal production technique/system
4. Development and installation of system modification(s) for silk-yarn drying
5. Trial test runs for fine tuning system design modifications
6. Field performance monitoring of the systems
7. Organization of project review workshop

Following sections give a detailed account of the project activities undertaken in order to achieve fruitful completion of the project to meet the project objectives.

Chronology of project activities

July 2001

- Preparation of schematic drawings for hot plate as well as hot air system for silk yarn drying
- Trial runs on testing viability of flexible layout of gasifier location using belt driven blower at TERI's Gual Pahari campus.

- Formation of project co-ordination committee
- Identification and selection of local fabricator for fabrication of heat exchanger as well as hot plate and hot air system
- Organization of the first project co-ordination committee meeting at Bangalore

August 2001

- Re-organization of the first project co-ordination committee meeting at Sidlaghatta
- Trial runs at TERI's Gual Pahari campus on obtaining charcoal using gasifier
- Fabrication of hot plate, hot air system and heat exchanger at Chikaballapur
- Installation of hot plate and hot air (including heat exchanger) system at Sri Gurumurthy unit in Sidlaghatta
- Trial runs on hot plate and hot air drying system at Sri Gurumurthy unit

September 2001

- Modifications in hot air (concave plate with series of holes on top located below reeling shaft instead of few small square air showers on side) and hot plate (location below reeling shaft instead of back side of reeling shaft) system
- Installation of modified hot plate and hot air system at Sri Gurumurthy unit
- Trial runs on modified hot plate and hot air system at Sri Gurumurthy unit

October 2001

- Modification of hot air pipe line (symmetrical air distribution) at Sri Gurumurthy unit
- Continuance of trial runs on hot plate and hot air system at Sri Gurumurthy reeling unit
- Replacement of big old blower with small belt driven blower at Sri Gurumurthy reeling unit
- Organization of the second project co-ordination committee meeting at Sidlaghatta

November 2001

- Field visit of MAG mission to Gurumurthy unit in Sidlaghatta
- Fabrication of proof of concept system of combined hot plate-hot air system at TERI's Gual Pahari campus.
- Trial runs on proof of concept system of combined hot plate-hot air system at TERI's Gual Pahari campus.

- Preparation of detailed drawings of combined hot plate-hot air system
- Identification and selection of fabricator for fabricating combined hot plate-hot air system for silk yarn drying

December 2001

- Modification of gas supply duct of burner (annular duct) for secondary air supply to producer gas burner
- Fabrication of combined hot plate-hot air system at M/s Electro System and Control, Bangalore
- Installation of combined hot plate-hot air system at Sri Gurumurthy unit
- Trial runs on combined hot plate-hot air system at Sri Gurumurthy unit

January 2002

- Start of comparative field performance monitoring data collection at Sri Gurumurthy reeling unit.
- Trials on enclosure to hot air and combined hot plate-hot air system in Sri Gurumurthy reeling unit.
- Preparation of detailed drawings of combined hot plate-hot air and hot air (including heat exchanger) system for Sri Anantha Padmanabha unit.
- Fabrication of a hot air and combined hot plate-hot air for the silk drying for Sri Anantha Padmanabha unit.

February 2002

- Field visit of SDC team to Sri Gurumurthy unit at Sidlaghatta for review of project progress.
- Continuation of comparative field performance monitoring for data collection at Sri Gurumurthy reeling unit
- Field visit of team of SDC, 2M Industries (gasifier manufacturer) and M/s Vijay Engineering (marketer) to Sidlaghatta gasifier field-testing sites.
- Relocation of gasifier in the corner at Sri Anantha Padmanabha unit.
- Installation of hot air and combined hot plate-hot air system at Sri Anantha Padmanabha unit.
- Trial runs on obtaining charcoal at regular intervals during gasifier operation at TERI's Gual Pahari campus.

March 2002

- Trial runs at Sri Gurumurthy unit for charcoal production using gasifier system
- Installation of twin belt driven blower at Sri Gurumurthy and Sri Anantha Padmanabha units.
- Trial runs at Sri Gurumurthy unit on withdrawing sufficient quantity of charcoal, required for silk yarn drying, at regular intervals during whole day operation of gasifier.

April 2002

- Comparative field performance monitoring for data collection at Sri Anantha Padmanabha unit and continuation at Sri Gurumurthy unit
- Field visit of Partners Forum Group-II MAG mission to Sri Gurumurthy unit
- Fabrication of hot plate system for charaka oven as a proof of concept to extend concept of using flue gas waste heat using hot plate for silk yarn drying.
- Project progress review meeting at SDC office

May 2002

- Continuation of comparative field performance monitoring for data collection at Sri Gurumurthy unit
- Trial runs on hot plate system for charaka reeling unit in Sidlaghatta as an extension of concept to use flue gas waste heat for silk yarn drying.
- Fabrication of waste heat recovery unit for charaka oven as a proof of concept to extend concept of using flue gas waste for preheating water.

June 2002

- Compilation and analysis of collected data
- Trial runs on waste heat recovery system in charaka oven at Sidlaghatta as an extension of the concept to use flue gas waste heat for water preheating.
- Project review-cum-future planning meeting at 2M Industries, Mumbai.

2

Project co-ordination committee meetings

In order to achieve smooth and fruitful completion of project activities and to have useful feedback from various stakeholders from time to time it was decided to form a project co-ordination committee. Accordingly project co-ordination committee was formed in July 2001 with representatives from SDC, TERI, DoS (TSC-Reeling, Sidlaghatta), representative reelers including gasifier users (Sri B M Gurumurthy and Sri Anantha Padmanabha). It was planned to hold these meeting at regular intervals viz. at the start of the project to plan project activities, after trial runs on proposed silk yarn drying system to get user feedback, after carrying out field performance monitoring and at the end of the project to review and plan future course of actions.

First project co-ordination committee meeting

First co-ordination committee meeting was originally planned in SDC, Bangalore on 31st July 2001, but both the reelers where gasifier system was installed could not attend the meeting. Therefore meeting was held with participation of members from TERI, SDC and DoS (TSC-reeling, Sidlaghatta). Since reelers are the main stakeholders of the project it was decided that the meeting be reconvened on next day at Sidlaghatta so that reelers can participate in the meeting.

Accordingly meeting was held in the office of TSC-reeling, Sidlaghatta on 1st August 2001. The main objective of this meeting was to brief the reelers and DoS staff about TERI's action plan for this phase of project and discuss with each stakeholder on their respective roles. Sri Srinivas, TERI explained the participants the purpose of the meeting and gave brief presentation about planned project activities.

Sri Mande, TERI informed that the main objective of this phase is to find out possible solutions for silk yarn drying problem and to arrive at an acceptable package of the gasifier based system. He told that the project activities would aim at

- Achieving flexibility of gasifier installation layout to enable reeler to accommodate gasifier in available space in the existing layout of the unit.
- To try out various possible options for silk yarn drying namely,
- Obtaining sufficient charcoal required for drying silk yarn using present traditional method

- Obtaining hot air by waste heat recovery from hot flue gases escaping through chimney using heat exchanger and distributing it over reels
- Passing hot flue gases through hollow plate below existing reeling shaft to dry silk yarn by radiation from hot plate surface
- Simplify the system design from operation and manufacturing point of view

After the discussions in the meeting it was decided that all the options of silk yarn drying would be tried out first at Sri Gurumurthy's unit as there is additional set of basins available with ample space and later on finalized version would be tried in Sri Anantha Padmanabha unit.

After the meeting all participants visited Sri Gurumurthy unit to understand the suggested modifications/options in a better way and during discussions reelers could also give some useful minor details and feedback which would be useful while actually developing and trying out various silk yarn drying options.

Second project co-ordination committee meeting

As planned earlier the second project co-ordination committee meeting was organized after carrying out few trial runs on silk yarn drying options at Sri Gurumurthy's unit. Representatives from TERI, TSC-reeling and reelers including gasifier users participated in the meeting held on 29th October 2001 at the premises of TSC-reeling, Sidlaghatta (Figure 2.1a). SERI 2000 officials could not attend the meeting due to their other prior commitments.

Sri Krishnamurthy, TSC welcomed all the participants and informed that the purpose of the meeting is to get the opinion of the reelers on the trials undertaken by TERI on various options of silk yarn drying.

Sri Mande gave brief presentation on the trials already undertaken by TERI at TERI's Gual Pahari campus near Delhi as well as at Sri Gurumurthy's unit on following aspects.

Silk yarn drying using hot air

The concept here is to capture the heat from flue gases passing through chimney to dry the silk yarn. The system consists of a heat exchanger in which fresh air is passed through insulated ducts surrounding chimney pipe. The heat from chimney flue gases is transferred to fresh air. Thus generated hot air is passed through ducts below the reel in a distributed fashion so that the hot air impinges on the moist silk yarn and dries it.

Silk yarn drying using hot plate

In this case hot flue gases are directly taken towards reeling shaft through insulated ducts and passed through annular plate placed below reeling shaft. The annular plate is insulated from bottom side. Top hot plate radiates heat to reeling shaft drying the silk yarn.

Charcoal production using gasifier

Though trials on using gasifier for charcoal production were satisfactory, the ratio of firewood to charcoal about 5:1 was observed i.e. about five kg firewood produces about one kg charcoal. This was felt to be on higher side and hence it was decided to optimize the process further to minimize firewood consumption.

After the meeting, visit was made to Sri Gurumurthy unit so that participants could see the actual drying of silk yarn using suggested options of hot plate and hot air system and give feedback for further improvisation (Figure 2.1b). Sri Gurumurthy said that he is satisfied with the performance of the system of gasifier with drying options. He mentioned that the observation period included cloudy and rainy weather and hoped that for rest of the season there would be further improvements. Two points he mentioned are as follows;

- He expressed that he would prefer hot air system to hot plate system for silk yarn drying. Hot air system gives more flexibility in its layout while the latter causes some hindrance to movement of reelers.
- He also said that if using waste heat for silk yarn drying is completely successful it would be better than producing charcoal using gasifier as it would not call for any additional fuel (firewood or charcoal) consumption for silk yarn drying.

Other reelers who visited also appreciated the concept of silk yarn drying (both hot plate as well as hot air). Following are the two points made by the reelers who visited the unit;

- Little higher temperature level might be required during cold mornings of winter and rainy season.
- In order to achieve higher temperature it would be good idea to try out combination of both the concepts (hot plate and hot air) in one system.

Project progress review meetings

During the course of project period several meetings were held with SERI-2000 team to review the progress of project at various stages as well as other partners (potential manufacturer and marketing agencies) to plan future course of actions. Brief experts of these meetings are summarized in the following sections.

MAG mission field visit

On 10th November 2001 MAG team of SERI 2000 made a visit to field testing site of TERI's gasifier based Italian oven system for carrying out half yearly review of the project progress. In the meeting at TSC-reeling office, Sidlaghatta TERI team briefed the mission members about the progress made in this project so far. DoS staff of TSC and reelers including gasifier users also participated in the meeting. The MAG team members then visited Sri Gurumurthy unit to see the actual operation of gasifier and silk drying options developed.

MAG team appreciated both hot air and hot plate systems and also the concept of using waste heat of hot flue gases for drying silk yarn. However they felt that these additional systems might result in higher system cost. They also brought to notice that experiments on producing charcoal using gasifier system have not been carried out and demonstrated under the field conditions.

Partners forum self appraisal workshop

A two day review workshop of all the partners of the SERI-2000 Programme of SDC was organized at Attibele between 30 November-1 December 2001. Each partner gave brief description of their project in the respective group (in this case it was post cocoon product development group) and shared their experiences (achievements, problems and future plans) with other partners as self-appraisal of the projects of the partners within their respective groups. Partners appreciated the project approach specially efforts to overcome the problem of power back up for gasifier operation; natural mode operation of gasifier and connecting blower required for gasifier to existing reeling shaft. They also appreciated the benefits of the gasifier technology being developed but few had apprehensions of its acceptability mainly due to initial investment requirement.

SERI-2000 team field visit

As a follow up action after the completion of MAG mission, SERI-2000 team made visit to field testing site at Sidlaghatta on 18th February 2002 in order to take stock of project progress and to plan future activities. Sri Vijayan, fabricator who fabricated the silk yarn drying system components (heat exchanger, hot plate combined hot plate and hot air system), also participated in this field visit.

During the meeting at TSC-reeling office TERI team explained them about progress of project activities (Figure 2.2 a). TERI team informed visitors that based on the feedback received from reelers in the second project co-ordination committee meeting combined hot plate-cum hot air system has been successfully developed and installed at Sri Gurumurthy unit. Information on trials carried out at TERI's Gual Pahari campus was also given to the team. After the brief meeting the SERI 2000 team along with fabricator visited Sri Gurumurthy unit (Figures 2.2 b).

SERI team appreciated combined hot plate and hot air system and the concept of using waste heat of hot flue gases for drying silk yarn. However they expressed concern over the fact that these additional system may call for additional initial investment and therefore may reduce the acceptability to some extent. Hence they advised the TERI team to accelerate the field trials to demonstrate possibility of using gasifier system for obtaining sufficient quantity of charcoal required for drying silk yarn using traditional method.

In the follow-up review meeting at SDC it was decided to invite potential manufacturer (M/s 2M Industries, Mumbai) and marketing agency (M/s Vijay Engineering Works, Bangalore) to visit field-testing site. Since system development activity is nearing its completion, this will give an opportunity to these stakeholders, who showed interest in gasifier technology promotion so far, to get an insight of target cluster as well as field performance of the system. It was also decided that pending project review workshop activity would be undertaken, if required, after manufacturer and marketing agency comes back with future plan to promote system after getting feedback from the field.

Accordingly on 20th February 2002 Sri Kulkarni of M/s 2M Industries, Mumbai and Sri Ravi of M/s Vijay Engineering, Bangalore visited Sidlaghatta along with representative from TERI and SERI-2000 to understand and see the field performance of the system (Figures 2.3 a and b). Later on during the follow-up meting at SDC, Bangalore they were asked to carry out quick assessment of the market and possible system cost estimate (both for manufacturing and promotion in the field) based on the feedback.

Field visit of Partners Forum Group-2, MAG mission

After experiencing the successful self-appraisal of various projects within the group by partners, during the workshop at Attibele in November 2001, it was decided to form the Partners Forum consisting of four groups in the meeting on 27th March 2002 organized by SDC in Bangalore. On a trial basis it was decided that each group will carryout preliminary desk review of all its partners project as well as field visits wherever required.

As a part of this Partners Forum Group-2 (post cocoon product development group) mission, desk review of the project was carried out on 22nd April 2002 in Bangalore and field visit was organized on 23rd April 2002. Members appreciated the field performance of the system and approach to overcome the problem of silk yarn drying; obtaining sufficient charcoal using gasifier system or using waste heat of hot flue gases to dry silk yarn. They also observed that quality of charcoal obtained using gasifier system is much better than that obtained from traditional ovens. However they felt that the system still looks complicated. TERI informed members that this is due to the fact that all possible options are being experimented here for demonstration in one unit and efforts would be made to simplify the layout for chosen configuration.

Meeting with SERI-2000 team for future planning

After the field visit of Sri Ravi of M/s Vijay Engineering, Bangalore and Sri Kulkarni of M/s 2M Industries Mumbai to field site in Sidlaghatta, TERI team gathered feedback from them on their interest and possible strategy for promoting gasifier based Italian oven. Based on the feedback received TERI team prepared an action plan for developing a commercial prototype for future large scale promotion and its field testing through collaborative effort which will also achieve technology transfer from technology developer to implementing agency.

On 20-21 June 2002 TERI team had meeting with SERI-2000 team at M/s 2M Industries, Mumbai to discuss the proposed plan and finalize future course of action. It was decided that the present ongoing project would be concluded without project review workshop. It was planned that in the following months TERI along with manufacturer (M/s 2M Industries, Mumbai) will evolve a commercial prototype unit which then will be shown to reelers for possible large scale promotion later on along with interested marketing agencies.

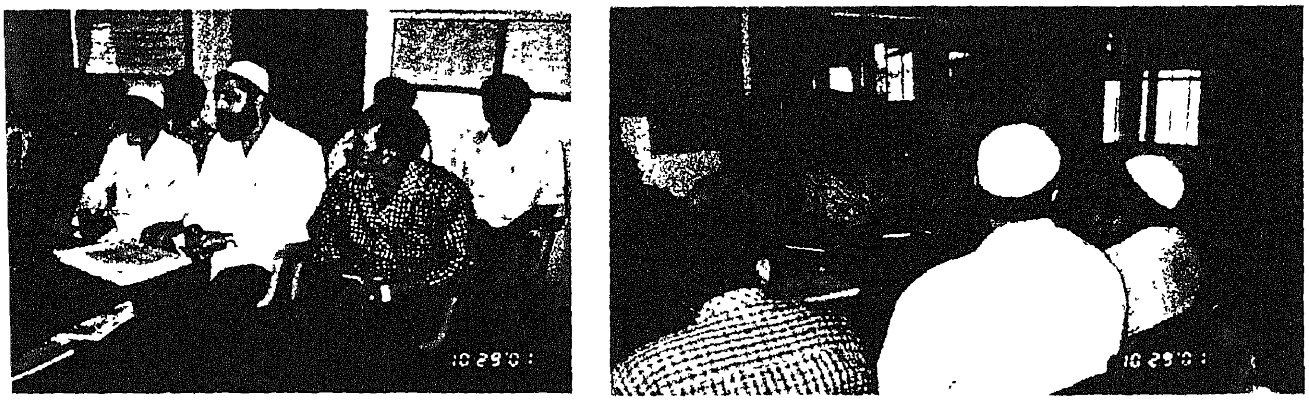


Figure 2.1a: Second project coordination meeting at TSC-reeling, Sidlaghatta

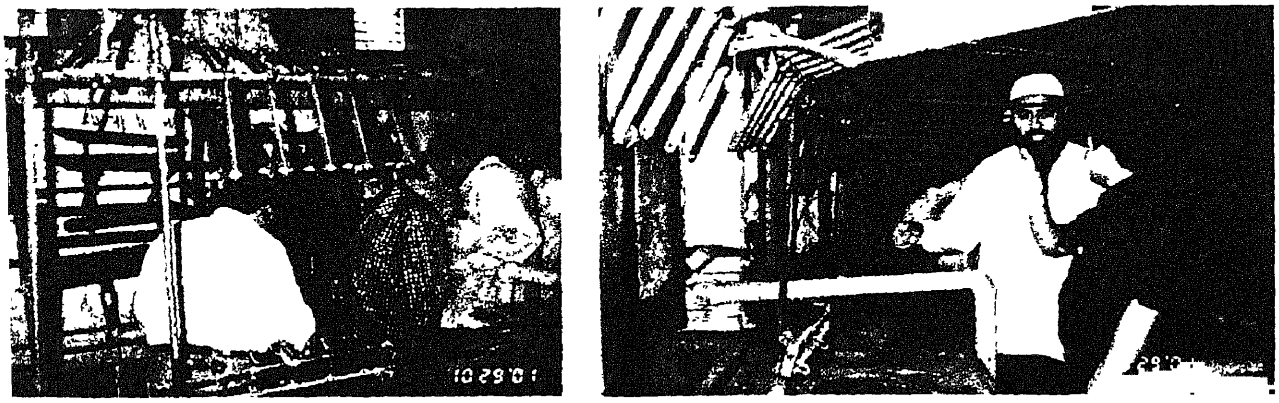


Figure 2.1b: Visit to Sri Gurumurthy unit to show various silk yarn drying options

(a) Meeting at TSC-reeling, Sidlaghatta

(b) Field visit to Gurumurthy unit

Figure 2.2. SERI 2000 team's visit to Sidlaghatta for review of project progress

(a) Meeting at TSC-reeling, Sidlaghatta

(b) Field visit to Gurumurthy unit

Figure 2.3: Visit of manufacturer and marketing agency to Sidlaghatta cluster

3 Flexibility in gasifier installation in existing layout

During the last phase of the project the updraft gasifier design was used for developing appropriate system for Italian cottage basin oven. This was also demonstrated on natural draft mode i.e. without using a blower to supply air. This configuration proved that the intervention of gasifier could even be operated in small reeling units where electricity is not available. During various discussions with the reelers and our own observation of small reeling units showed that the requirement of electricity is likely to be one of the major hindrances for promoting gasifier based system that requires electricity. But, this configuration has certain limitations which are listed below:

- Gasifier has to be located at a lower elevation and hence a pit may be required to be made so that gas outlet comes at ground level in order to ensure rising air and gas flow under natural draft mode from lower to higher level in its path.
- Gasifier has to be installed at equidistant in the center with respect to both the burners (cooking basins) in order to ensure equal power levels (gas supply).

However, these were found to be limitations in the existing reeling units. In order to overcome these limitation and considering the fact that most of the Italian cottage basin ovens are quite congested, reelers felt that it would be better if one can install gasifier wherever space is available to accommodate it. This flexibility may help in enhancing the acceptability of the gasifier-based system.

The objective of this activity was therefore to overcome this problem in order to achieve flexibility in installing updraft gasifier system in the existing layout. It was decided to test the concept in TERI first and then take it to the field for demonstration and performance monitoring under the field conditions.

Trial runs at TERI's Gual Pahari campus

An updraft gasifier system requires relatively small power to supply air in order to ensure consistent and controlled quantity of air supply as per the requirement. In the last phase concept of coupling blower to the existing reeling shaft was proven successfully both in Sri Gurumurthy as well as in Sri Anantha Padmanabha unit. However the blower used in the last phase of the project was quite bulky. Therefore it was decided to try out compact pulley driven twin blower (single shaft with impellers on both ends and pulley at the center), which can be easily mounted on the reeling shaft. After overcoming the problems of imbalance of both the impellers through proper balancing of the shaft a compact twin blower was custom made for trial purpose with the help of local blower manufacturer in Delhi. Twin blower also gives additional advantage i.e. with only one pulley-belt arrangement two blowers can be operated. One blower can be used to supply primary air to the gasifier and other blower can be used to supply secondary air into the burner ducts for achieving premixed air+gas mixture in the burner. Two separate blowers also enables independent and better control on air supply to gasifier and that to gas burners.

The gasifier, which was earlier located in a pit was now placed above the ground level. The gasifier outlet was taken down to ground level and then taken to cooking basin to supply gas to burners so that it would not hamper movement of the operator. The gasifier was located at a sufficiently long distance (almost more than a length of the two table of Italian oven) so that it would simulate a situation in the field, where gasifier can even be installed in any one remote corner of the existing Italian basin oven layout as per the availability of the space (Figures 3.1). Several trials were made in order to see that sufficient and consistent desired power levels could be obtained with the changed configuration.

After verifying the consistent and reliable operation of gasifier as mentioned above, the same configuration was replicated in both Sri Gurumurthy unit and Sri Anantha Padmanabha's units in Sidlaghatta (See Figures 3.2).

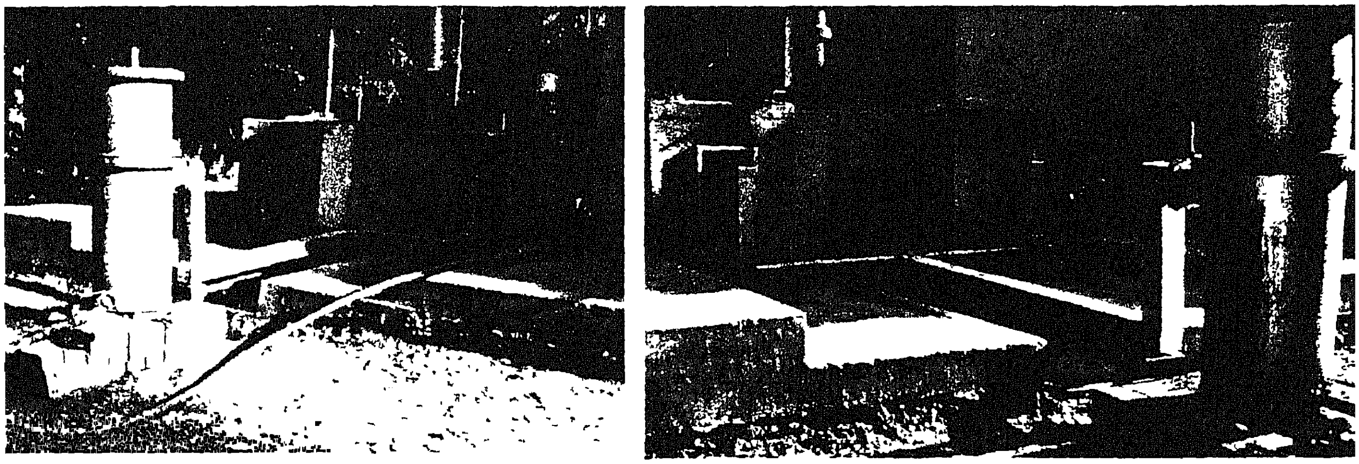


Figure 3.1. Proof of concept testing in achieving flexible layout of gasifier at Gual Pahari

Figure 3.2: Gasifier installed at ground level in Gurumurthy and Anantha Padmanabha unit

4

Charcoal production using gasifier system

The trials of producing charcoal production using gasifier were initiated from a feedback received during the design review workshop of the last phase of the project. Though the reelers appreciated the benefits of the gasifier-based system, it was felt that there should be solution to silk yarn drying, as one of the apprehension based on the present operation, the gasifier does not produce charcoal. It was also clear that this was one of the critical elements for the acceptance of the new intervention. The concept of drying silk yarn using waste heat recovery from hot flue gases was in principle agreeable, as it minimizes fuel consumption. But the apprehension on this system was the additional incremental investment cost. Therefore it was decided to make trials to produce sufficient charcoal from gasifier itself. Though this may reduce the fuel saving benefit to some extent, it would perhaps enhance the acceptability of the basic gasifier model.

The major objective of this activity is therefore to obtain sufficient charcoal from gasifier system for use in present traditional method followed for silk yarn drying where hot charcoal is placed below reeling shaft.

In order to obtain charcoal from gasifier two different options were tried which include:

Gasifier as charcoal producer

Using gasifier as charcoal producing unit (pyrolyzer) to produce large quantity of charcoal by pyrolyzing fuelwood pieces in the gasifier in overnight batch operation.

Charcoal removal from gasifier during the operation itself

Removing charcoal at regular intervals from gasifier during its operation without affecting the stable flame of producer gas in the burner.

Initially trial runs were carried out in TERI's Gual Pahari campus as proof of concept for both the options and then few field trials were carried out at Sri Gurumurthy's unit to confirm field replication and demonstrate viability of both the options under field conditions.

Method 1: Using gasifier as wood pyrolyzer for producing charcoal

In order to convert existing gasifier into wood pyrolyzer following minor modifications were made in the gasifier system:

End plug at the bottom of the gasifier

End plug with small hole is used to fit into the socket (which is provided at the bottom of the gasifier below the grate to supply air into gasifier) so that required air is supplied to achieve slow pyrolization of wood pieces inside gasifier (Figure 4.1 a). Through series of trials it was found that 16-mm diameter hole size is sufficient to achieve required pyrolysis.

Modification of the top lid of the gasifier

Gasifier top cover was fitted with half-inch diameter ball valve (Figure 4.1 b). This helps in flaring the pyrolysis gases during initial period. The valve is then closed completely to stop further combustion of fuelwood inside gasifier.

The procedure adopted to obtain sufficient charcoal from gasifier in one overnight batch operation is as follows:

Charging of firewood

Remove the gasifier top cover and fill it completely (till flue gas outlet) with dry cutwood pieces inside the gasifier. This can be done at the end of the last batch on working day; preferably last working day of the week.

Ignition

Keep the top lid of the gasifier open and allow the wood pieces inside the gasifier to burn (in case of fresh operation ignite the fire below grate and allow wood to burn) keeping air inlet fully open till the fire/flame reaches top layer of the wood. The escaping gas that is combustible after initial short period can be flared to minimize smoke emission.

Flaring of pyrolysis gases

Afterwards close the gasifier top lid and keep vent valve open (Figure 4.2 a). Place the end plug with a hole inside the air inlet socket. Flare the pyrolysis gases coming out of vent valve to minimize smoke level.

Cutting out the air supply

After sufficient time when the entire fuelwood bed gets converted into charcoal, close the vent valve in order to stop the air supply into the gasifier completely to die down the combustion process of wood/charcoal.

Removal of charcoal

After cooling down (preferably the following day morning) of gasifier to some extent remove the charcoal by opening the gasifier top lid.

During the trial operations at TERI's Gual Pahari campus and also during field trials for demonstration at Sri Gurumurthy's unit (during March 2002) it was observed that charcoal produced to fuelwood consumed ratio lies in the range of 1:4 to 1:5.

The major advantage of this method is that it does not call for additional capital investment for silk yarn drying in the existing set up of gasifier based Italian oven system. However the possible drawbacks or inconveniences associated with this method observed during field trials-cum-demonstration include:

Smoky operation

Lot of smoke is emitted during initial ignition of fuelwood bed inside gasifier, especially during the period when gasifier top lid needs to be kept open.

Operational inconvenience

If the gasifier does not cool down completely till next day it becomes difficult for the operator to remove hot charcoal pieces from top from warm gasifier. This may happen more frequently during hot season when reeling operation starts early in the morning and gasifier also cools down slowly due to surrounding hot ambient conditions.

Require skilled operation

Experience and skill is required to understand the process and to decide when to close the gasifier top that would convert entire fuel bed into charcoal. Many times some uncharred wood remains inside gasifier if gasifier top is closed early or early stoppage of air by complete closure of vent valve.

Reduced fuelwood saving

Additional fuelwood is required to produce charcoal through pyrolysis of wood inside gasifier.

Method 2: Removal of charcoal from gasifier at regular intervals

In order to overcome the inconveniences mentioned above and to minimize the fuelwood consumption for obtaining charcoal it was decided to see if sufficient quantity of charcoal can be removed from the gasifier without disturbing its operation; i.e. destabilizing flame in the burner (Figure 4.2 b).

For verifying the viability of the concept several trials were carried out to decide

(a) the frequency of charcoal removal (time interval between subsequent removal of charcoal) and
(b) quantity of charcoal which can be removed safely without disturbing producer gas flame in the burner.

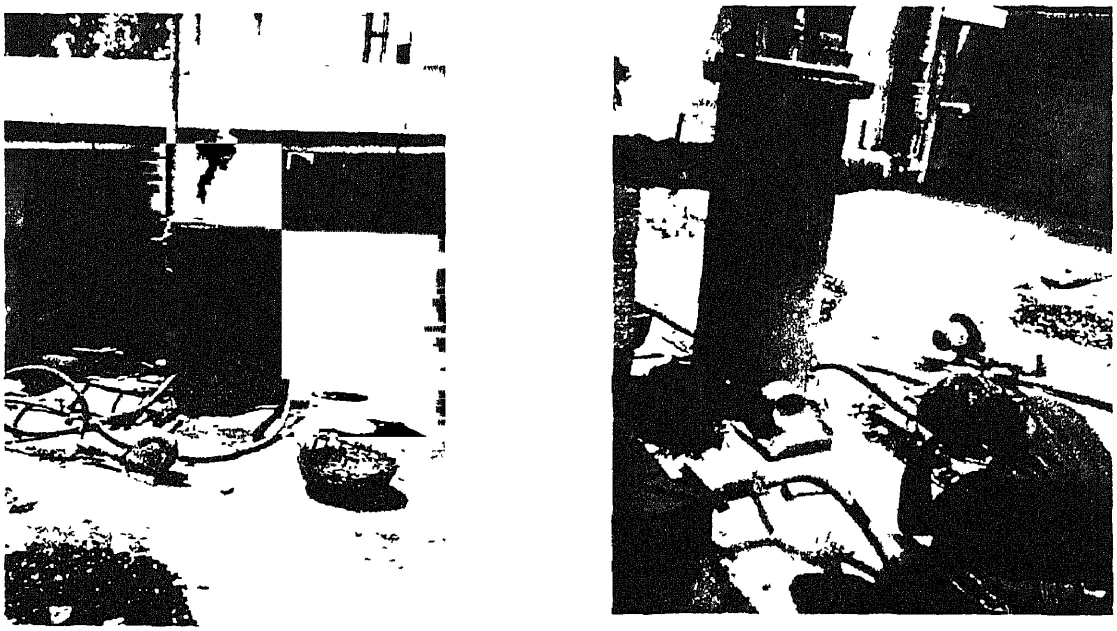
It was found out that one could remove about 250 to 350 gm charcoal at every half an hour interval without disturbing the normal operation of gasifier. Thus throughout the day's operation (9 hrs) it is possible to obtain about 4.5 kg charcoal. This quantity of charcoal is sufficient (for all seasons including winter when higher quantity of charcoal is required for silk yarn drying) for silk yarn drying for 4 reeling basins, which can be operated using one gasifier system.

This was demonstrated at Sri Gurumurthy's unit during March-April 2002. Unlike in Method 1, the pyrolysis gases are not wasted into the atmosphere in Method 2. The net amount of fuel used to obtain charcoal is also less. Thus charcoal is actually obtained as a by-product from the gasifier during its operation. It was observed that additional wood consumption is much less as compared to earlier method, i.e. about 2.5 to 3.5 kg of firewood is required to produce 1 kg of charcoal.

(a) End plug with hole at air inlet

(b) Vent valve on gasifier top cover

Figure 4.1 Modifications in gasifier to produce charcoal in batch operation



(a) Charcoal production in batch operation

(b) Charcoal removal during gasifier operation

Figure 4.2. Field trials of obtaining charcoal required for silk yarn drying using gasifier

5

Development of various silk-yarn drying systems

This chapter gives a detailed account of developmental efforts made to develop various technological options for silk yarn drying in Italian cottage basin (Sidlaghatta type) oven. The overall objective of this activity was to make use of heat content of hot flue gases, which other wise wasted through chimney, for drying silk yarn. This also thus minimizes the additional charcoal required for silk yarn drying.

Proof of concept testing at Gual Pahari

The main objective of this proof of concept testing in the laboratory was to see whether there is any adverse effect of putting additional resistance in flue gas path (in the options of silk yarn drying that include is passing flue gases through duct-cum-annular plate in hot plate or through heat exchanger in hot air system) on stable operation of producer gas burner. A prototype of Italian oven constructed at TERI's Gual Pahari campus during the earlier phase of the project was used to carry out trials.

Some simulation exercises were carried out to simulate the field conditions at the laboratory. A semicircular annular plate was fabricated and installed behind the Italian basin table comprising of two cooking basins. The length of this annular hot plate was equivalent to four reeling shaft of Italian basin in Sidlaghatta. Flue gas chimney inlet was closed and gases were allowed to pass through duct towards backside that connects cooking basin with hot plate. Care was taken that the hot plate is located at higher elevation than flue gas outlet from cooking oven, similar to situation in the field, to have natural movement of flue gases towards exit without necessity of any driving force in the form of blower or exhaust fan.

Proof of concept testing under field conditions

Based on the successful trials at Gual Pahari, i.e. obtaining stable gas burner operation in spite of additional resistance in flue gas path, following two options of silk yarn drying were tried out simultaneously in Sri Gurumurthy's unit:

Hot air system

This system comprises of heat exchanger (tube in tube annular heat exchanger) for waste heat recovery. The hot flue gases are used to obtain hot air. The hot air is further distributed using insulated pipeline network and showers located near reeling shaft.

Hot plate system

This system comprises of insulated gas duct, which carries hot flue gases from cooking basin to reeling basin. Hot plate, which is an annular box located around reeling shaft (insulated from outer side), radiates heat to the silk yarn thereby drying it.

After identifying one local fabricator in Chikkaballapur, first version of hot plate (see Figure 5.1 a and b) and hot air system comprising of flue gas waste heat recovery heat exchanger (see Figure 5.2a and Annexure 2a) were installed at Sri Gurumurthy's unit for trials. The air shower system (see Figure 5.2b and Annexure 2b) to distribute heated air over reeling shaft is also shown in the figure.

Trial runs on the system proved the concept that it works and it is possible to utilize heat content of the hot flue gases escaping through chimney for drying silk yarn. Sri Gurumurthy and other reelers who visited during trial runs gave following comments:

- Hot air system is preferable over hot plate system. Hot air system provides flexibility in its layout. It does not hamper operator movement as hot air is carried through insulated pipeline network. However it needs an additional blower for circulating air through heat exchanger and distributing heated air over reeling shafts.
- In case of hot plate, the hot flue gas is carried by natural draft (thus does not need additional blower). But the flue gas duct that runs across from cooking basin to re-reeling basin hampers the movement of reelers.
- It was felt that positioning of hot plate at the bottom of the reeling shaft would be more effective. This would also allow using of additional charcoal on it during rainy conditions to supplement the heat, if required, for drying silk yarn.
- The present hot air showers consisted of rectangular boxes with holes. There were chances of mismatch of relative positioning and the hot air may escape unutilized and also may not dry the yarn uniformly. This aspect was also pointed out and it was felt that hot air distribution system be made in concave shape and placed at the bottom of the reel (with lengthwise series of holes on its topside along the edges) to blow hot air over the silk yarn on reeling shaft.

Accordingly modified system was fabricated in a local workshop at Chikkaballapur and installed at Sri Gurumurthy's unit. Detailed drawing of modified hot plate and hot air system is given in Annexures 2c and 2d respectively. Photographs in Figure 5.3 and 5.4 show the view of hot plate and hot air system respectively.

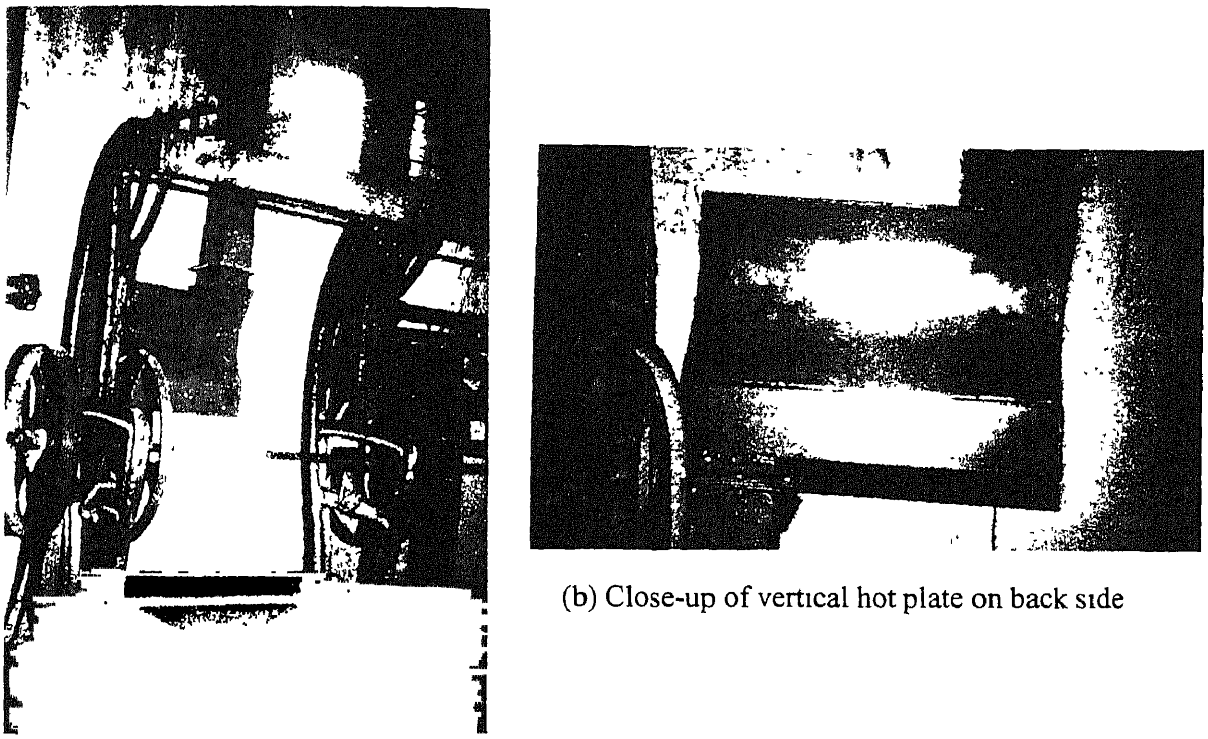
Development of combined hot plate+hot air system

During the second project co-ordination committee meeting the reelers felt that the temperature achieved with the above systems might not be adequate during winter/monsoon seasons. Hence they felt the combination of both hot plate and hot air in one system may help achieving higher temperature and improve silk yarn drying.

In this system hot flue gases are carried from cooking basin to re-reeling basin similar to hot plate system. The central lower portion of the system gets heated up which radiates the heat towards reeling shaft from inner top hot surface. Annular duct around the hot flue gas duct acts like heat exchanger recovering heat from its surface. This heated air is flown around the hot plate on bottom outer side and on sides and comes out through series of holes provided along lengthwise edge of the hollow hot air box. Since here hot flue gas duct as well as hot plate is covered with hollow annular air passage insulation requirement is reduced substantially. Similar to hot air system small blower is required to circulate air through annular hollow passage and blow it over reeling shaft.

Proof of concept of this combination was tested at TERI's Gual Pahari campus in November 2001 and few trial runs were conducted on the system to gain confidence (Figure 5.5). The system was fabricated as per detailed drawing of combined hot plate+hot air system (Annexure 2e) under TERI's supervision by M/s Electro System and Control, Bangalore in December 2001. The system was installed in Sri Gurumurthy's unit in Sidlaghatta for monitoring its performance (See Figure 5.6). Trials were carried out to enhance silk yarn drying by covering the reeling shaft completely with enclosure (Figure 5.7). However, later on this idea was discarded since it was hampering removal of the reeling shaft and also putting on broken thread during reeling operation.

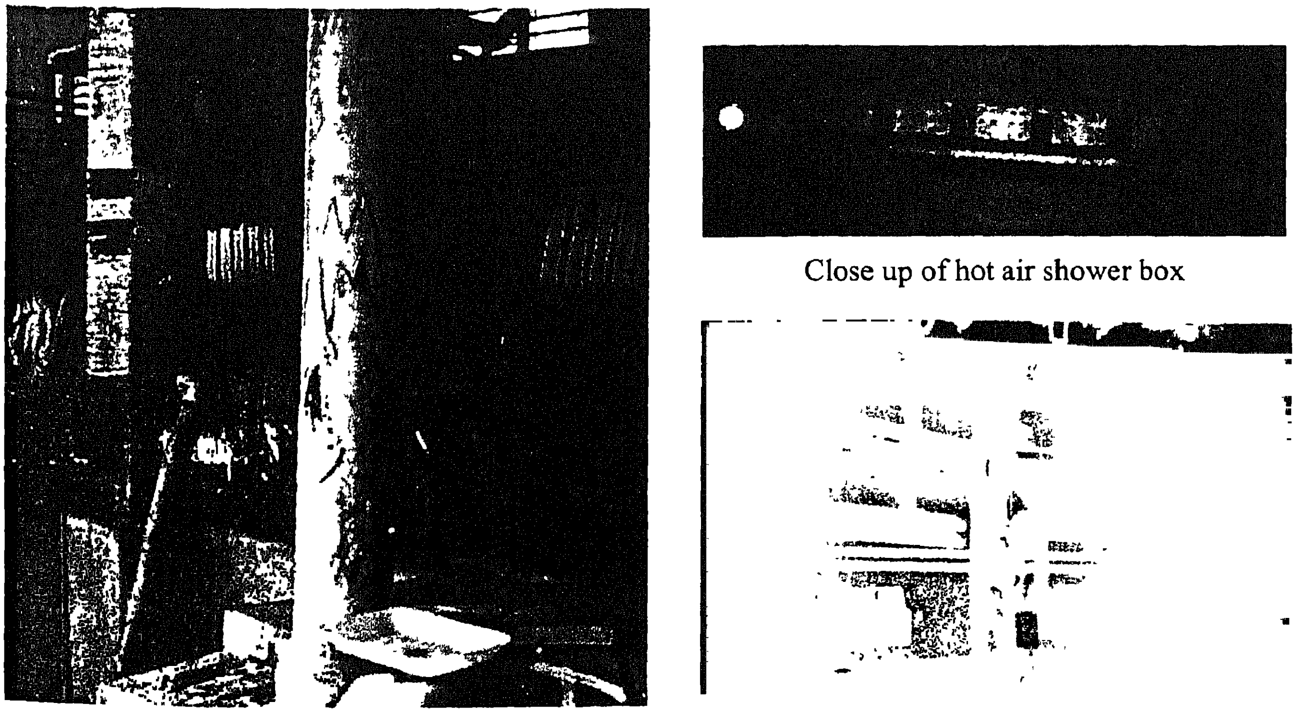
After carrying out trials in Sri Gurumurthy's unit the drawings were prepared for Sri Anantha Padmanabha unit and the system components were got fabricated in Bangalore in January 2002 (Figure 5.8 a and b). However comparative performance evaluation experiments could be initiated in Sri Gurumurthy and Sri Anantha Padmanabha's unit respectively from February and April 2002 only. Details of these results are given in next chapter.



(b) Close-up of vertical hot plate on back side

(a) Vertical hot plate on back side

Figure 5.1: Proof of concept testing of hot plate system for silk yarn drying in Sidlaghatta



Close up of hot air shower box

(a) Flue gas waste heat recovery heat exchanger

(b) Hot air system for silk yarn drying

Figure 5.2: Proof of concept testing of hot air system in Sidlaghatta

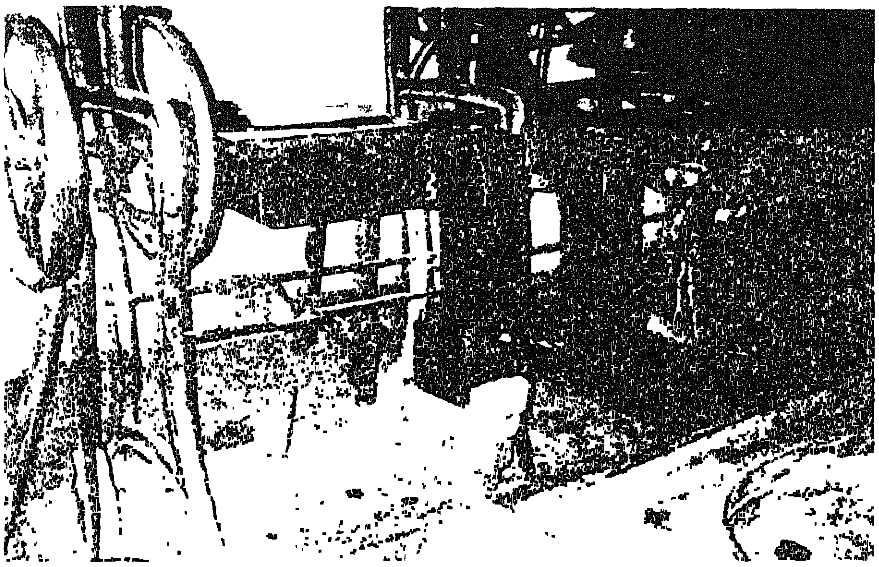


Figure 5.3. Modified hot plate system installed at Gurumurthy unit

Figure 5.4. Modified hot air system installed at Gurumurthy unit

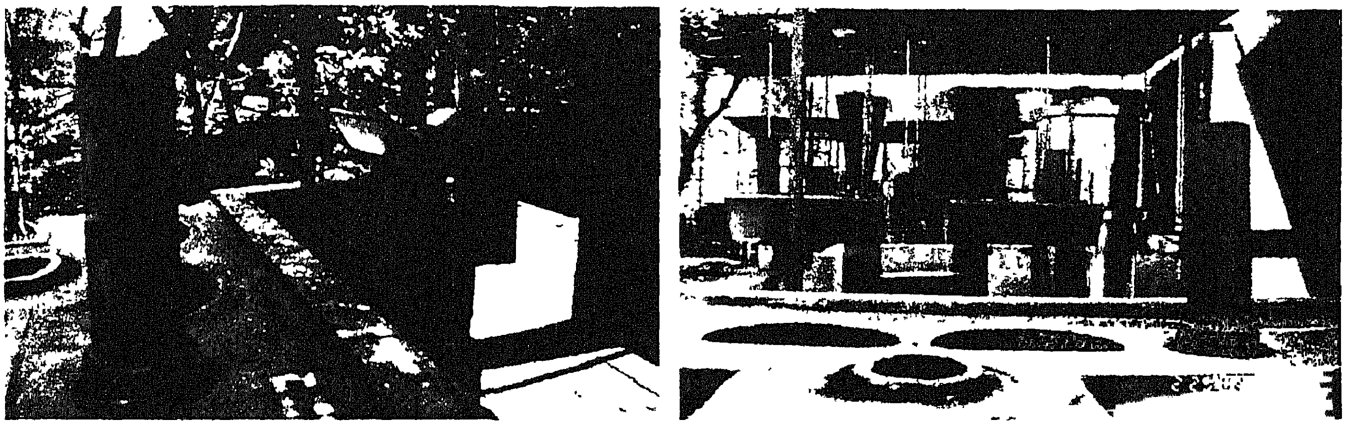


Figure 5 5: Proof of concept testing of combined hot plate+hot air system at Gual Pahari

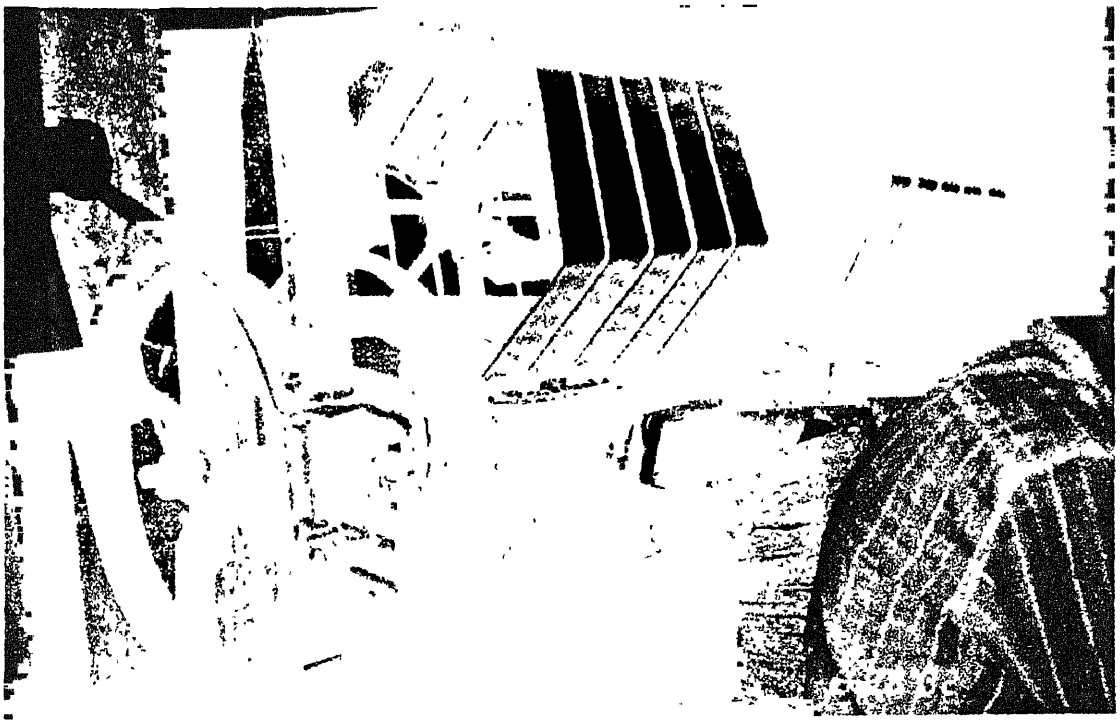


Figure 5.6: Combined hot plate+hot air system installed at Gurumurthy unit

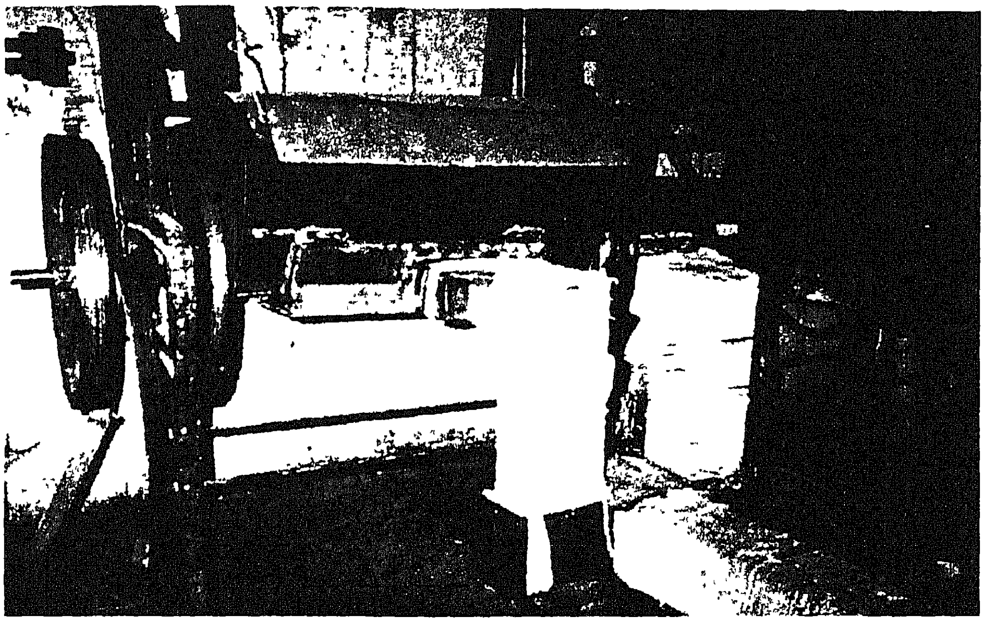
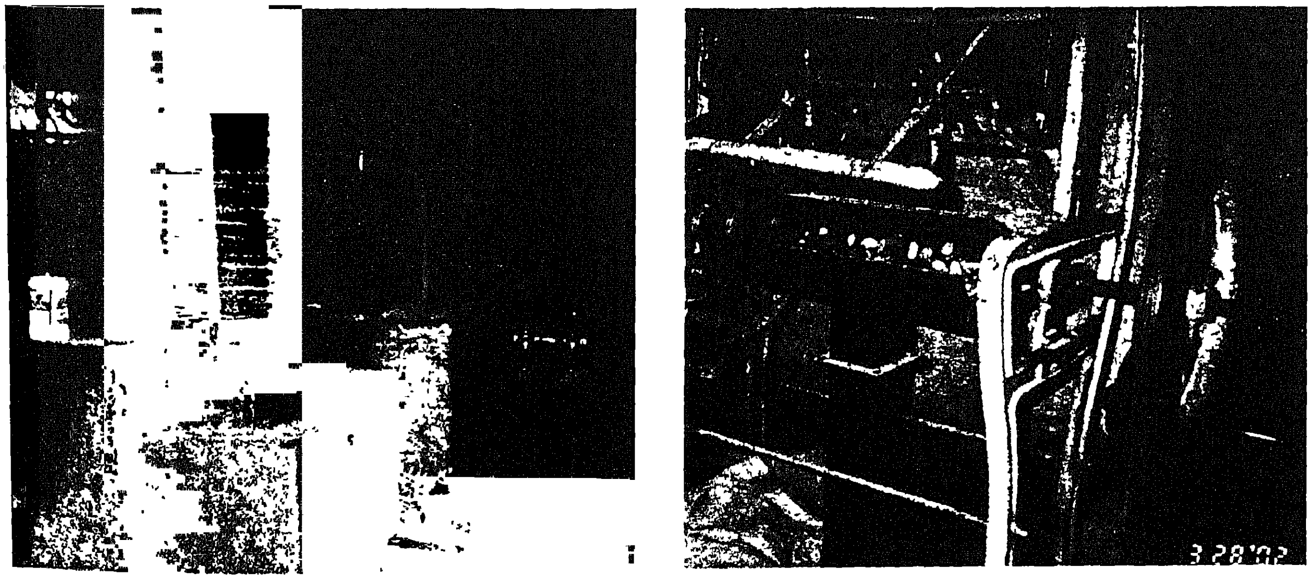


Figure 5.7: Trials with enclosure around reeling shaft to enhance drying



(a) Flue gas waste heat recovery heat exchanger

(b) Modified air system

Figure 5.8: Silk yarn drying system using waste heat recovery installed at Anantha Padmanabha unit

6

Field performance monitoring

The monitoring to assess the performance was initiated after installation of both the silk yarn drying options viz. hot air system and combined hot plate+hot air system in both Sri Gurumurthy and Sri Anantha Padmanabha's reeling units. The main objectives of the field performance monitoring were,

(i) to monitor the gasifier and silk yarn drying option performance under field conditions and

(ii) also to compare it with that of traditional Italian basin ovens in order to enable techno-economic analysis of proposed options.

While collecting the data efforts were made to minimize the variations in operating parameters to the extent possible under field conditions. Efforts were also made to minimize the error due to human factor such as operator skill by interchanging operators (cooking as well as reeling persons) randomly.

Field performance data analysis of Italian cooking oven

While monitoring the field performance data on any particular day sometimes different number of cooking basins and reeling basins were monitored on conventional oven and in gasifier based systems. This was because the operation depended on the availability of the cocoon and also number of workers on that day. However for the sake of comparison, the quantification was made for two cooking ovens, i.e. four reeling basins. This was done since one gasifier system is designed to provide sufficient combustible gas for two tables (two cooking basins and four reeling basins) of Italian oven. On each day comparative data was monitored on both traditional and gasifier system for one to three batches operated on that day.

In all the comparative data could be measured for 36 days and 15 days in Sri Gurumurthy and Sri Anantha Padmanabha's reeling units respectively. The detailed performance monitoring data collected for both conventional and gasifier system in both these units is given in Annexure 3.

Fuelwood saving

The main objective here was to verify the fuel saving benefit of gasifier based system vis-à-vis traditional oven. Comparative field performance data with regard to fuelwood saving benefit is summarized in Table 6.1.

Table 6.1: Comparative field performance data: fuelwood saving

Parameter	Gurumurthy		Anantha Padmanabha	
	Conventional	Gasifier	Conventional	Gasifier
No of data points	36		15	
Specific fuel consumption	3.984	2.857	3.847	2.438
(kg wood per kg cocoon)	(0 914)	(0.572)	(1.545)	(0 985)
Wood saving (%)	27 231		35 927	
	(9 638)		(7 067)	
Wood consumption rate	3.368	2 277	3 137	1 926
(kg/hr/CB)	(0.475)	(0.176)	(0 305)	(0 120)
Wood saving (%)	31 481		38 014	
	(8.050)		(6 486)	

Note: Numbers in parenthesis are standard deviation values

The wood consumption comparison is made both in terms of specific fuel consumption (kg wood per kg cocoon processed) and wood burning rate (kg/hr per cooking basin). It can be observed that specific fuel consumption in gasifier based cooking oven was 27 to 36% lower as compared to conventional Italian cooking oven. If comparison is made with regard to wood burning rate, fuelwood saving is of the order of 31.5 to 38% by using gasifier based Italian oven. These values are 3-7% lower than those observed during last year. The reasons could be relocation of gasifier from pit to farther position as well as use of different blower.

Silk yarn yield and renditta

During last year's comparative performance data monitoring indications of improvement in silk yarn quality and renditta (increased silk yarn yield) were observed though the increase in absolute term was quite small. Therefore this year the comparative data on silk yield was collected to see and verify this benefit. The techno-economic viability would perhaps be highly favourable if there is indeed increase in silk yield in addition to fuelwood saving benefit. Comparative field performance data with regard to renditta and silk yarn yield is summarized in Table 6.2.

Table 6.2: Comparative field performance data: renditta and silk yarn yield

Parameter	Gurumurthy		Anantha Padmanabha	
	Conventional	Gasifier	Conventional	Gasifier
No of data points	36		15	
Renditta	4 854 (1.011)	4 803 (1.011)	5 939 (1.238)	5 792 (1.191)
Renditta improvement	0.052 (0.134)		0.147 (0.117)	
Increase in silk yarn yield (%)	1.196 (2.889)		2.492 (1.912)	

Note: Numbers in parenthesis are standard deviation values

It can be observed that there is a definite trend with gasifier based system in increased silk yarn yield. The percentage increase in silk yarn yield observed was about 1.2 and 2.5 % in Sri Gurumurthy and Sri Anantha Padmanabha unit respectively. Reelers also appreciated the uniformity in quality of silk yarn that can be attributed to

(i) uniform heat supplied for silk yarn drying with minimal exposure to charcoal smoke and

(ii) uniform cooking of cocoons in cooking basin due to consistent power levels from gas burner.

Field performance data analysis of silk yarn drying options

The effectiveness of various silk yarn drying options tried was evaluated by monitoring the silk yarn drying by using charcoal in traditional method in one reeling basin and other reeling basin using either hot plate or hot air system for charcoal consumption. Since maximum charcoal is consumed during rainy or winter conditions, care was taken to monitor the performance for 15 days during winter season at Mr Gurumurthy unit (Annexure 4). Table 6.3 gives the summary of the charcoal consumption data for conventional and hot plate/ hot air system/combination for silk yarn drying.

Table 6.3: Comparative charcoal consumption for silk yarn drying in winter (Traditional Vs silk yarn drying using waste heat)

Parameter	Silk yarn drying system		Silk yarn drying system	
	Traditional	Hot plate	Traditional	Hot air
No of data points	15		15	
Charcoal consumption (gram/RB/day)	1052.86 (283.09)	275.71 (107.77)	1035.00 (242.24)	296.07 (186.52)
Charcoal saving (gram/RB/day)	756.79 (189.30)		759.29 (213.68)	
Charcoal saving (%)	71.88		73.36	

Note: Numbers in parenthesis are standard deviation values

It can be observed from the table that the charcoal consumption is reduced by about 72 to 74% by using waste heat recovery for silk yarn drying using hot plate and hot air system respectively. These options though could not completely eliminate the charcoal consumption, the reduction is as high as 70%. Thus with the new options only a small quantity of charcoal is required especially during first batch in the early morning hours. This is due to the fact that apart from colder ambient condition the system takes some time to get heated up during initial period before it starts functioning effectively. Once the system achieves steady state hot condition silk yarn drying can be achieved effectively without need of additional hot charcoal. This 20% charcoal required can be obtained easily from the gasifier without hampering its stable operation.

7

Cost benefit analysis for various configurations

As now development phase is coming to concluding stage and product is more or less ready for its test marketing in target cluster there is need to carry out detailed techno-economic feasibility of proposed intervention. In this section therefore an attempt has been made to make cost-benefit analysis of gasifier based Italian oven system for various silk yarn drying configurations tried out during this project phase. The calculations are based on the data procured from field monitoring. Since the gasifier-based system has been designed to supply energy requirement for two tables (two cooking basins and four reeling basins) the analysis has been done for two tables on daily basis.

In order to get more realistic idea of system cost for various configuration the information was obtained from M/s 2M Industries, Mumbai and M/s Vijay Engineering enterprises, Bangalore for manufacturing and marketing cost (which includes for system installation, training also) respectively have been considered. It is to be noted that both these costs are on higher sides for initial few systems for test marketing phase. Afterwards the unit cost is expected to be reduced over a period of time. The various configurations considered are as follows:

Basic gasifier model

Updraft gasifier, two burners with associated ducts, twin-blower either electric or pulley driven

Basic gasifier model + Hot air with heat exchange

Basic gasifier model, two waste heat recovery heat exchangers, four hot air distributing plate along with associated ducts, set of additional twin blowers

Basic gasifier model + combined hot plate & hot air

Basic gasifier model, four hot plate-cum-hot air units along with associated annular ducting, set of additional twin blowers

The incremental investment costs considered for these configurations are summarized in Table 7.1.

Table 7.1: Incremental investment cost details for various system configurations

Sr. No.	System configuration	Manufacturing cost (Rs)	Marketing cost (Rs)	Total cos (Rs)
1	Basic gasifier model	12,000	7,250	19,250
2	Basic gasifier model + Hot air with heat exchanger	32,500	10,000	42,500
3	Basic gasifier model + combined hot plate-hot air	21,000	10,000	31,000

While carrying out the cost benefit analysis the average values of various parameters observed during comparative performance monitoring in Sri Gurumurthy and Sri Anantha Padmanabha's units in Sidlaghatta were considered. Conservative estimates and conditions are considered while arriving at daily monetary benefits to the reeler. For example charcoal consumption during winter season is considered in the analysis though it is known that actually it varies from season to season, maximum being during rainy and cold winter morning conditions while minimum during hot-dry shiny days. Similarly the additional kerosene consumption is considered for the entire day's operation instead of considering only for the power cut duration.

Since various configurations of silk yarn drying have been tried out and proposed the cost benefit analysis has been carried out for all the four configurations listed below:

- Basic gasifier model and outsourcing charcoal required for silk yarn drying
- Basic gasifier model and producing charcoal using gasifier system for drying
- Basic gasifier model and hot air system with heat exchanger for drying
- Basic gasifier model and combined hot plate-cum-hot air system for drying

The details of the cost benefit analysis for all the four configurations considered are given as Annexure 5. Table 7.2 and 7.3 summarizes the data with regard to daily monitory benefit and simple payback period for incremental capital investment required for various system configurations considered.

Table 7.2: Daily monitory benefits (Rs) for various configurations of gasifier based Italian oven system

Configuration	Daily monitory benefits (Rs)			
	Gurumurthy		Anantha Padmanabh	
	Fuel saving	Fuel saving + more silk	Fuel saving	Fuel savin more sil
Basic gasifier model, charcoal out sourced	8 36	71 79	16 25	140.18
Basic gasifier model, charcoal from gasifier	7.56	70.99	15 45	139 38
Basic gasifier model and hot air system	12.74	76.18	20 64	144 57
Basic gasifier model and combined hot plate-hot air	19 62	83 06	27 52	151.45

It can be observed from Table 7.2 that even though improvement in renditta is small in absolute value it gives several times higher monitory benefits (Rs 63-124 per day) as compared to fuelwood saving (Rs 8 to 28 per day) alone. Daily monitory benefits are lower (of the order of Rs 8 to Rs 16) with basic gasifier system alone whether charcoal is produced in gasifier or outsourced. Since combined hot plate-cum hot air system requires one additional blower less compared to hot air system it gives higher fuel saving benefit, as less kerosene would be required to operate the blower. Large variations in fuelwood saving as well as improvement in renditta observed in two field units monitored clearly indicates that there is large scope to improve benefits by better operating practice and management.

Table 7.3: Simple payback periods for various configurations of gasifier based Italian oven system

Configuration	Incremental cost (Rs)	Simple payback period (year)			
		Fuel saving only		Fuel saving+more silk	
		Gurumurthy	Anatha Padmanabha	Gurumurthy	Anantha Padmanabha
Basic gasifier model and outsourcing charcoal	12,000	4 787	2.461	0 557	0.285
	19,250**	7 679	3.948	0 894	0 458
Basic gasifier model and charcoal from gasifier	12,000*	5 294	2.589	0 563	0 287
	19,250 *	8 492	4 153	0.904	0.460
Basic gasifier model and hot air system	32,500	8.503	5.250	1.422	0.749
	42,500 *	11.120	6 865	1 860	0.980
Basic gasifier model and combined hot plate-hot air	21,000*	3.568	2.544	0.843	0.462
	31,000**	5 267	3 755	1 244	0.682

* Manufacturing cost only

** *Manufacturing cost + marketing cost*

Simple payback period for various configurations also varies according to daily monitory benefits. For basic gasifier model the simple payback period is in the range of 4 to 8.5 years if one considers fuel saving benefits only (with quoted manufacturing and marketing costs) and come down to less than a year if one considers monitory benefits due to increased silk yield on account of improvement in renditta. Similarly for gasifier system along with hot air system and combined hot plate-hot air system the simple payback period works out to 7-11 years and 4-5 years respectively if fuel saving alone is considered and 0.7-2 years if benefits due to renditta improvement are also taken into account. However it should be kept in mind that when the market grows up the unit system cost will come down closure to manufacturing cost thereby resulting in much lower payback period.

8

Extension of waste heat recovery concept for improving charaka oven

In this chapter brief account of efforts made to extend the concept of waste heat recovery from flue gas for useful purposes in charaka reeling oven are described. This activity was not included in the original project proposal but was undertaken to test the feasibility of the concept when one charaka reeler from Sidlaghatta showed interest in extending help (after seeing it in Gurumurthy unit) in carrying out concept testing in the field in his unit.

In case of charaka oven an arrangement of recovering the heat from hot flue gases and using it for either silk yarn drying or water preheating would be easier to introduce. These methods would perhaps be more effective in charaka reeling ovens as cooking and reeling operation is done in close vicinity.

Fuel used in majority of the Charaka ovens is loose biomass or wood waste. Type of biomass used also changes seasonally depending upon availability of biomass in local area. While carrying out detailed study of ovens used in silk reeling sector in the past project it was observed that the operating efficiency of existing conventional charaka ovens is very low of the order of 5-15% and most of the heat is wasted through hot flue gases escaping from chimney. In charaka ovens the heat loss through chimney is comparatively much higher due to fast burning loose biomass used in these ovens to attain desired high power levels demanded by process.

Waste heat recovery for silk yarn drying

Approximately 4-6 kg charcoal is burnt below the reeling shaft to dry the silk yarn to process one-kg yarn. Charcoal burnt below reeling shaft is major source of pollution apart from high level of smoke due to loose biomass burning resulting in poor working environment causing health hazard due to excessive exposure to smoke. Also approximately 4-6 kg wood is required to produce one-kg charcoal that means indirectly huge quantities of fuelwood are consumed in charaka ovens too apart from loose locally available biomass.

Since, most of the charaka units use loose biomass the charcoal required for silk yarn drying is bought out (Rs 4-6 per kg) from the market thus any saving in charcoal consumption would result in improving the profit margin of the poor charaka reeler. Since charcoal used for silk yarn drying is also major source of pollution it was felt that the concept tried out in Italian basin oven can be effectively and economically introduced in charaka units. Also absence of exposure to smoke and charcoal spark, more uniform heating of silk yarn during reeling process may result in improving the silk produced in charaka oven using proposed new system. This again can boost charaka silk demand, which is supposed to be inferior in quality in the present market.

Therefore a simple proof of concept unit was fabricated and tried out to see the feasibility of the proposed concept in one of the charaka reeling unit in Sidlaghatta (Figures 8.1 and Annexure 6 a). The feedback received from the user (reeler) and experience during trial testing is quite encouraging. The results indicated that there is substantial scope of reducing charcoal consumption (and even possibility of eliminating use of charcoal also can not be ruled out through appropriate system development) which can result in direct monitory benefit to reeler. Also reeler felt that silk quality in terms of shine and breakage is better due to absence of direct exposure to smoke and charcoal burning sparks.

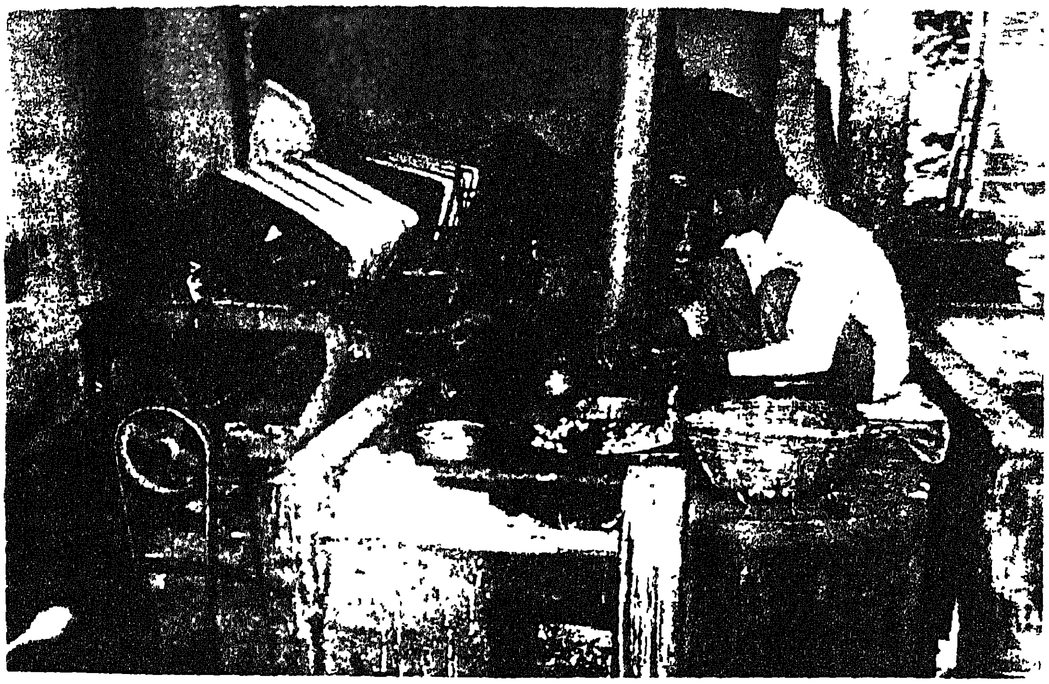
Waste heat recovery for water preheating

In order to test the usefulness of the waste heat recovery concept for water preheating a small tube in tube type heat exchanger was designed in place of flue gas chimney. Since about 12 litters of water is refilled after every batch in charaka oven the size of the heat exchanger was so designed that it can hold more than 20 litres of water (Annexure 6 b)

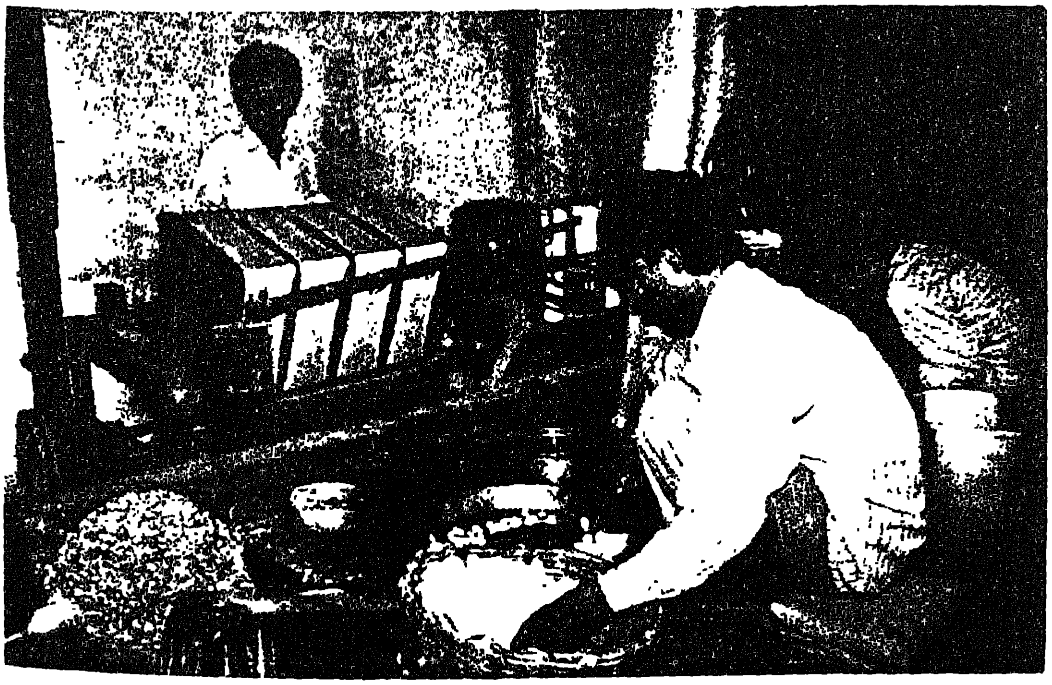
Initially the heat exchanger was made up of GI sheet (Figure 8.2a). However, the reeler reported that there was some shade in the silk yarn if the cocoons are cooked in water preheated in it. Since the reelers gave encouraging response to the concept and appreciated the usefulness, one more heat exchanger for water preheating was fabricated using SS sheet and installed (Figure 8.2b).

During trial runs it was observed that the water temperature goes upto 80°C at the end of the batch of 1.5 hr duration i.e. before it is transferred into the cooking vessel for next batch. This also saves the 25-30 minutes time of the operator which is normally required to heat up the water from ambient temperature to over 80°C after replenishing the water in the cooking basin after every batch. This time saving can help the charaka reeler to process more cocoons per day.

Also it was observed that in order to process about 15 kg of cocoons per day the daily fuel consumption is reduced to 38 kg as compared to that of 48 kg observed in traditional charaka oven. Thus there is more than 20% fuel saving when water preheater is installed in charaka oven, which can be attributed to the fact that fuel burning rate of loose biomass is reduced due to additional resistance of water preheater in flue gas path without actually affecting power level.

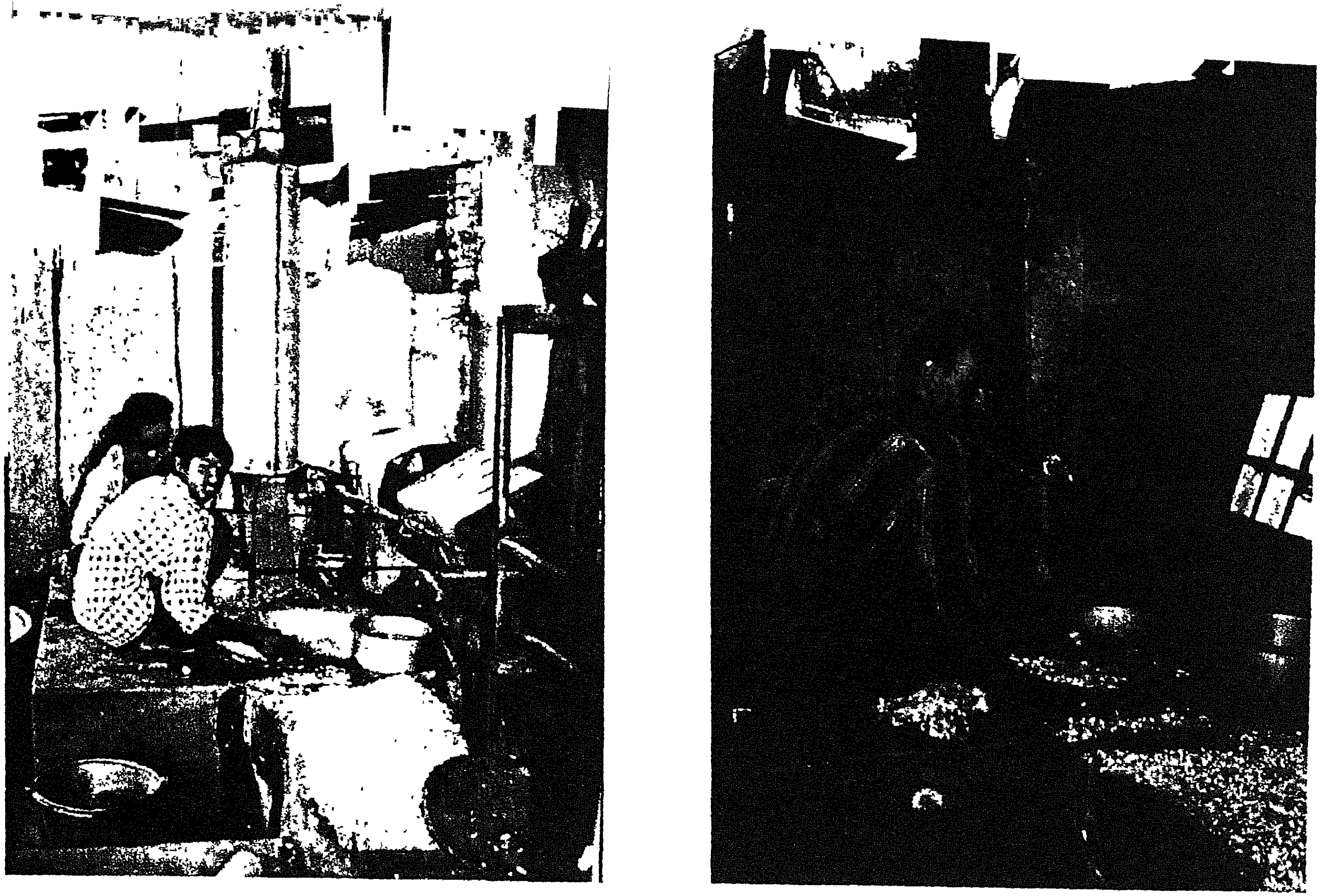


(a) Side view



(b) Front view

Figure 8.1 Proof of concept testing of extending concept of waste heat recovery for silk yarn drying in charka oven in Sidlaghatta



(a) GI sheet water preheater

(b) SS sheet water preheater

Figure 8.2: Proof of concept testing of extending concept of waste heat recovery for water preheating in charka oven in Sidlaghatta

9

Conclusions and recommendations

At the end of the last phase of the project, a review workshop was conducted with all the stakeholders. Though the users appreciated the basic model of the gasifier that gave a saving of fuel by about 40% over the traditional oven, they indicated that it would become really acceptable only if acceptable solution for silk yarn drying is evolved. The charcoal comes, as by-product in the traditional oven but is unable to get it from the gasifier. Hence, the mandate of the current phase was to look at the issue of silk yarn drying either by producing charcoal or other alternative methods such as using waste heat of hot flue gases escaping through chimney.

In the present project sponsored by SDC under its SERI-2000 programme, TERI had successfully developed and demonstrated various options of overcoming the problem of silk yarn drying using gasifier based system in order to arrive at improved system design configuration. These are namely (a) obtaining sufficient quantity of charcoal required for silk yarn drying using gasifier system, and (b) using heat content of flue gas for silk yarn drying which is otherwise wasted. In the former option, two methods were demonstrated, (i) producing charcoal from the gasifier while the gasifier is in operation without destabilizing the flame at the cocoon cooking vessel, (ii) Using gasifier as pyrolyzer for charcoal production in batch process. In the later options three different configurations were tried viz.(i) hot plate (in which flue gases are passed through semi-circular hollow duct placed below reeling shaft so as to act like radiant hot plate) system, (ii) hot air (in which hot air is generated through flue gas waste heat using heat exchanger and sprayed over reeling shaft) system, and (iii) combined hot plate plus hot air system (which is a combination of both radiant heat of hot plate and spraying hot air obtained through flue gas waste heat recovery).

The gasifier system with the above options was demonstrated at two units in Sidlaghatta for long duration and monitored for its comparative performance with that of conventional Italian oven system. It was observed that apart from substantial (30-40%) fuelwood saving gasifier system gives numerous other benefits. The major benefits of gasifier based system over conventional Italian oven are:

- Reduction in fuelwood consumption of the order of 30-40%.
- Obtaining sufficient quantity of charcoal required for drying silk yarn from gasifier itself.

- Reduction in charcoal consumption by about 70 % by using heat content of hot flue gases which otherwise is wasted through chimney.
- This not only reduces the charcoal consumption and fuel cost associated with it but also substantially improves the working condition, as charcoal burning below reeling basin is major source of CO emissions in the reeling units.
- Also since now silk yarn is not exposed to flying ash particles due to charcoal burning helps in improvement of silk yarn quality. Some of the women reelers mentioned during discussions said that the charcoal burning sparks off some particulates in hot condition on their back (since the shaft and reel rotate at considerable speed) which hurt them.
- Consistent heat input to cooking basin as well as for silk yarn drying.
- An increase in silk yarn yield (about 1.2-2.5%) was observed from 51 data points (36 in Gurumurthy unit and 15 in Anantha Padmanabha unit) from both the units.

Detailed cost benefit analysis of the various gasifier based system configurations has been carried out. The daily monetary benefit for basic gasifier model works out to Rs 8-16 with fuel saving alone and Rs 70-140 if income due to increased silk yarn yield is also considered. For hot plate or hot air system the daily monetary benefit ranges from Rs 12-28 from fuel saving alone and Rs 76-151 if income from increased silk yarn yield is included.

For basic gasifier model the simple payback period works out 4 to 8.5 years, if one considers fuel saving benefits only (with quoted manufacturing and marketing costs), and come down to less than a year if one considers monitory benefits due to increased silk yield on account of improvement in renditta. Similarly for gasifier system along with hot air system and combined hot plate-hot air system the simple payback period works out to 7-11 years and 4-5 years respectively if fuel saving alone is considered and 0.7-2 years if benefits due to renditta improvement are also taken into account. However it should be kept in mind that when the market grows up the unit system cost will come down closure to manufacturing cost thereby resulting in much lower payback period.

Though all the silk yarn drying options have been successfully developed and demonstrated in the field with their respective benefits, it was decided that the basic gasifier model (gasifier + two burners and associated ducts) with option for charcoal production can be promoted immediately. During the combined interaction of project team, manufacturers, and SDC, the manufacturer M/s 2M Industries expressed opinion that there are still possibilities of improving the model from manufacturer's point of view which will increase marketability of the system. Commercial prototype of this basic gasifier model could be developed in collaboration with manufacturer, which then can be promoted in the field by interested implementing/marketing agency. Other silk drying options can go as additional modules for those who are interested and are ready to invest additional cost for the same.

It was also felt that there is a need to achieve smooth transfer of technology know-how from technology developer to implementing agencies like manufacturer and marketing agency.

ANNEXURE 1

Action Research for Commercialization of Gasifier Systems for Silk Industry
Phase-3: Development of improved gasifier-based Italian oven (Sidlaghatta cottage basin) prototype

Time period: The mandate shall be executed during the period from 1st July 2001 to 31st March 2002

1.0 Background

The Sidlaghatta cluster is considered to be the best quality silk yarn producing cluster of Karnataka fetching higher premium price in the market. The layout of cocoon cooking oven and reeling is typical and quite different (without having re-reeling process) from other clusters and is called Italian basin (Sidlaghatta cottage basin) silk reeling oven.

After carrying out extensive survey of Sidlaghatta cluster (to know present energy use pattern) and energy audit of selected ovens (to study existing oven and to obtain design base for alternative design) an energy efficient gasifier system laboratory design was developed in the earlier phase of the project. During the last years's phase of the project the field prototype was fabricated and installed at two selected sites in Sidlaghatta for long duration field testing to monitor its field performance and obtain useful feedback for improvising the system design to arrive at marketable product.

1.1. Rationale

At the end of long duration field testing of gasifier based Italian cottage basin oven system in two units at Sidlaghatta a field demonstration of the units was organized on 12th June 2001 at Sidlaghatta followed by project-cum-design review workshop. Several progressive reelers (including users of gasifier system), officials from various organizations such as DoS-Karnataka, KSSRDI, SDC, TERI participated actively in this workshop. Almost everyone appreciated the performance and usefulness of the gasifier system. Several suggestions came forward during the discussions of the workshop in order to improve the system to meet reeler's expectations so as to become acceptable and marketable product. The main concern of the reelers was either to get sufficient charcoal or some alternative arrangement for drying silk yarn during reeling process.

The major aim of this phase of the project is to improve the system design based on the feedback received in design review workshop so that it can meet most of the reeler requirements and thus result in more user-friendly, acceptable marketable product.

2.0 Objectives and Outputs

2.1 Objectives

The major objectives of the proposed phase of the project are:

- improvising the system design (modifications in present retro-fitting gasifier option) based on feedback received during the project review workshop of earlier project phase.
- Field testing of the improved prototype design under performance evaluation
- Documenting the findings of the project phase in the form of reports etc.

2.2 Outputs

- Improved system design configuration of gasifier based Italian cottage basin oven
- Performance data of improved system design under field conditions

3.0 Methodology

The whole set of project phase activities to meet above said objectives are divided into following two sub groups:

A. Development and field testing of improved system design of gasifier based Italia cottage basin oven

B. Miscellaneous

The following is the list of activities required to be undertaken in order to achieve the proje objectives.

A. Development and field testing of improved system design of gasifier based Itali cottage basin oven

1. Formation of project co-ordination committee
2. Organization of project co-ordination committee meetings
3. Development and testing of charcoal production technique/system
4. Development and installation of system modification(s) for silk yarn drying
5. Trial test runs for fine tuning system design modifications
6. Field performance monitoring of the systems
7. Organization of project review workshop

B. Miscellaneous

1. Preparation of project progress reports
2. Project meetings.
3. Documentation of the work done.

Given below is a brief description of each of the activities for Development and field testing of improved system design of gasifier based Italian cottage basin oven

A1. Formation of project co-ordination committee

In order to achieve smooth and fruitful completion of project activities and to have useful feedfack from various stakeholders from time to time a project co-ordination committee will be formulated at the start of the project phase Representatives from DoS, progressive reelers, SDC, TERI will be members of this committee Representation for organizations such as KSSRDI will also be invited for having their valuable inputs.

A2. Organization of project co-ordination committee meetings

First meeting of the project co-ordination committee will be organized at the start of the project phase to plan and get suggestions for activities of this phase of the project Similar meetings will be organized once the improved system and systems modifications are installed at the site and another after carrying out performance monitoring of the system under field conditions.

A3. **Development and testing of charcoal production technique/system**
In the present gasifier system design the availability of sufficient charcoal for silk yarn drying was reeler's major apprehension Here efforts will be directed to overcome this problem by developing and testing charcoal production technique using existing set up or by alternate simple system design.

A4. **Development and installation of system modification(s) for silk yarn drying**
This activity will be aimed at developing system modifications (in oven and in gasifier system) to find out alternative viable option to achieve silk yarn drying. This will be useful to improve acceptability of retrofitting option of gasifier system in existing layout.

A5. **Trial test runs for fine tuning system design and system modifications**
After carrying out system design modifications in retrofitting option trial test runs will be carried out to fine tune the system design modifications in order to make it more user-friendly and achieve the desired performance

A6. **Field performance monitoring of the systems**
After installation and commissioning of the system design modifications in retro-fitting option regular performance monitoring of the gasifier based system will be carried out under field conditions.

A7. **Organization of project review workshop**
At the end of the project phase a project review workshop will be organized either in Bangalore or at Sidlaghatta Representative from various stake holder organizations, institutions and progressive reelers will be invited for participating in this workshop. The major objective of this workshop will be to review the progress and achievements of the project phase and also plan future course of activities to achieve ultimate goal of commercialization of the developed system/technological intervention.

Given below is a brief description of miscellaneous activities.

B1. **Preparation of project progress reports**
Preparation of required project progress reports as per MAG format.

B2. **Project meetings.**
During the course of the project, various meetings will take place with associated partners and SDC officials. This will help in carrying out corrective measures during the course of the project and future strategy planning.

B3. **Documentation of the work done.**
The purpose of this activity is to collect the experience gathered through out the project work, experimental data, findings of the system developed will be compiled for future reference. This will also help in utilizing this material for disseminating the information about the improved system to reeler community and to create awareness among them about the technological developments.

4.0 Project organization and management

1. Dr V V N Kishore (Advisor)
2. Mr Sanjay Mande (Project Co-ordination)
3. Mr S N Srinivas

5.0 Monitoring and evaluation

- The Monitoring and Advisory Group (MAG), the body created under SERI 2000, would undertake two monitoring missions in a year, generally during the months of November and May.
- TERI shall furnish physical and financial monitoring report to SDC-CMU as of 30 September and 31 March every year. The reports are expected to reach SDC-CMU latest by 15th of October and April every year.
- In addition, SDC-CMU shall follow the project activities including field visits and discussions, whenever necessary.

6.0 Payment schedule

(i) The first instalment (50% of total budget) of Rs 7,42,000/- (Rupees seven lacs forty-two thousand only) will be paid after signing of the agreement

(ii) Second installment (30% of total budget) of Rs 4,45,200/- (Rupees four lakh forty-five thousand two hundred only) shall be paid at the end of six month upon submission of the project progress report and unaudited statement of account and its approval SDC.

(iii) The balance amount will be paid at the end of the project on submission of the project report and an audited statement of account and its approval by SDC.

Detailed budget

I **Budget**

(a) **Personnel costs**

Person	Rate (Rs/manmonth)	Time (manmonth)	Amount (Rs)
Senior Fellow	1,81,983	0.5	90,991.50
Fellow (One)	1,20,650	2.5	3,01,625.00
Research Associate (Two)	92,148	2	1,84,296.00
Research Assistant (One)	61,231	2	1,22,462.00
Field Technical Assistant (Two)	42,388	6	2,54,328.00
Total professional time cost			**9,53,702.50**

(b) **Hardware and consumable cost estimate**

Sr. No.	Item	Amount (Rs)
1. Fabrication		
a.	Prototypes of gasifier based system and charcoal making system (both at TERI Delhi and field units)	1,00,000
2. Equipments		
a.	Repair, maintenance, up gradation of instruments	30,000
3. Consumables		
a.	Firewood/kerosene/diesel for lab and field testing	40,000
b.	Repair maintenance of gasifier based system components	30,000
	Total hardware and consumable cost	2,00,000

© **Travel cost and per diem**

Travel	1,00,000
Per diem	1,00,000

(d) **Technical specifications, Drawings, Manuals etc.**

Preparation of detailed technical specifications, drawings, manuals etc.	30,000

(e) **Workshop and meeting**

Workshop and meeting	50,000

(f) **Field expenses**

Modifications in the field system at field sites	50,000

Total - I	**14,83,702.50**
(Rounded to)	**14,84,000**

Time activity chart for project "Phase-3: Development of improved gasifier-based Italian oven (Sidlaghatta cottage basin) prototype"										
Work activity		Months								
		1	2	3	4	5	6	7	8	9
A.	**Development & field testing of improved gasifier based Italian basin oven**									
1.	Formation of co-ordination committee									
2.	Organization of co-ordination committee meetings									
3.	Development and testing of charcoal production technique/system									
4.	Development and installation of system modification(s) for silk yarn drying									
5.	Trial test runs for fine tuning system design and system modifications									
6.	Field performance monitoring of the systems									
7.	Organization of project review workshop									
B.	**Miscellaneous**									
1.	Preparation of project progress reports									
2.	Project meetings									
3.	Documentation of the work done.									

ANNEXURE 2
Detailed Technical Drawings of Gasifier based Italian Cottage Basin Oven

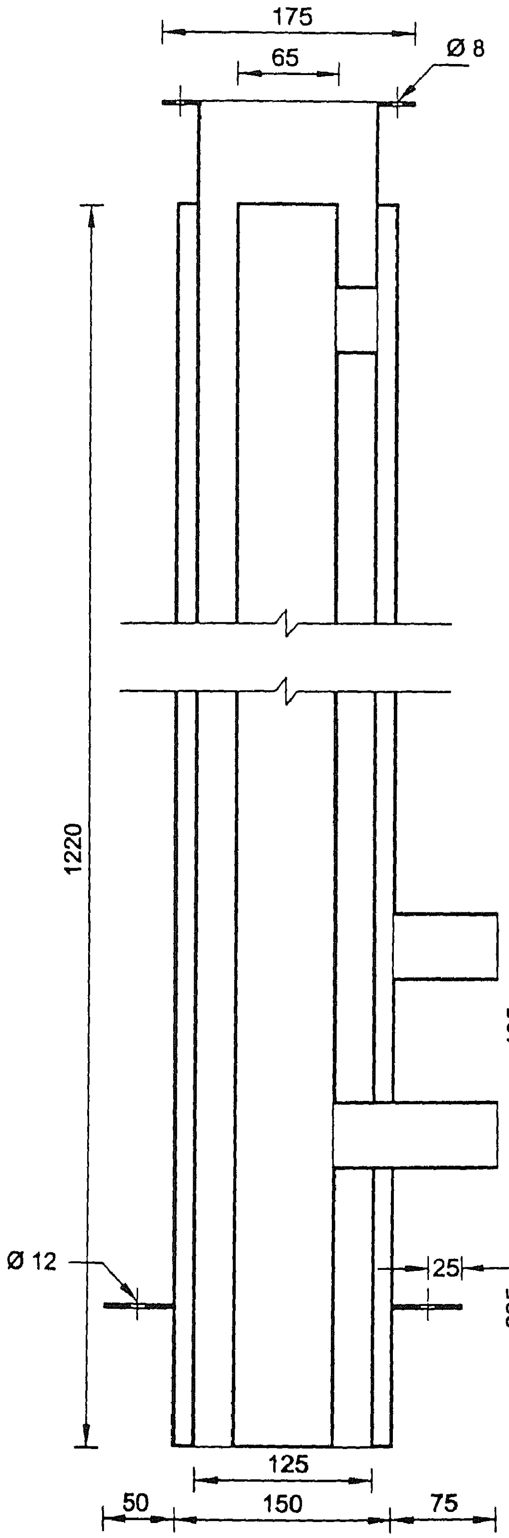
a. Heat Exchanger (Air heater using flue gas waste heat)
Drawing No TERI/BETA/2001BE42/HE-01

b. System for silk yarn drying (Hot air spray arrangement)
Drawing No TERI/BETA/2001BE42/HTAIR-01

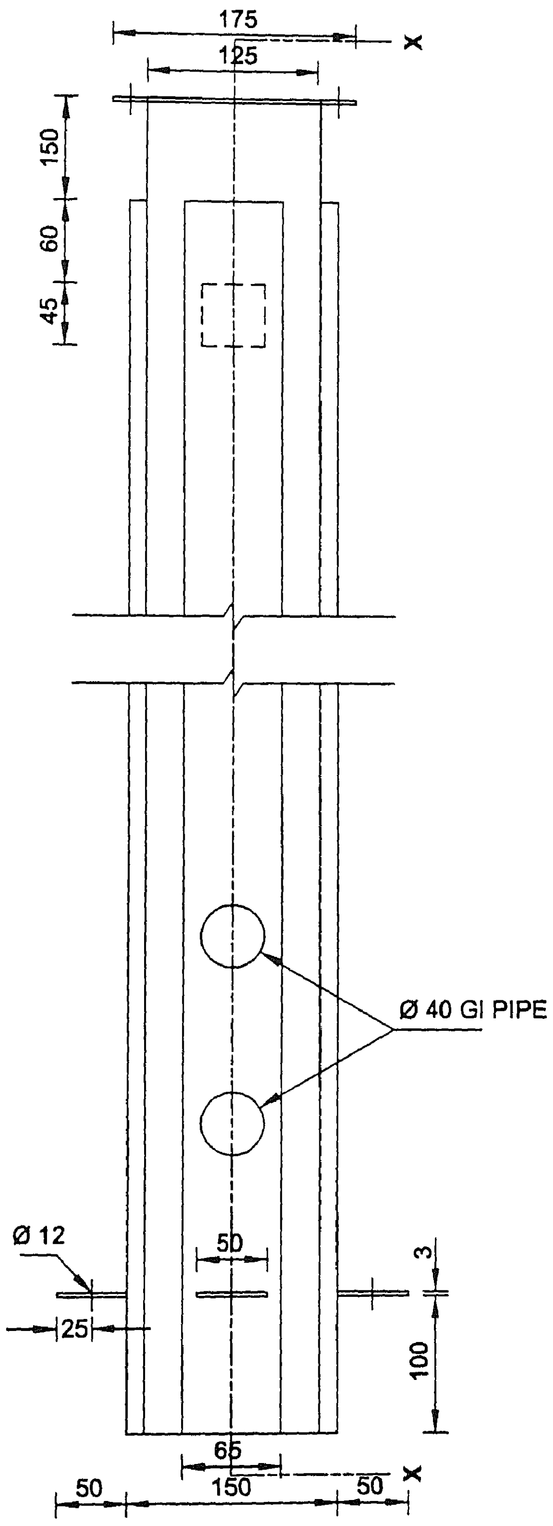
c. System for silk yarn drying (Hot air annular plate arrangement)
Drawing No TERI/BETA/2001BE42/HTAIR-02

d System for silk yarn drying (Hot plate arrangement)
Drawing No. TERI/BETA/2001BE42/HTPLT-01

e. System for silk yarn drying (Combined hot plate + hot air arrangement)
Drawing No TERI/BETA/2001BE42/C-HP+A-01



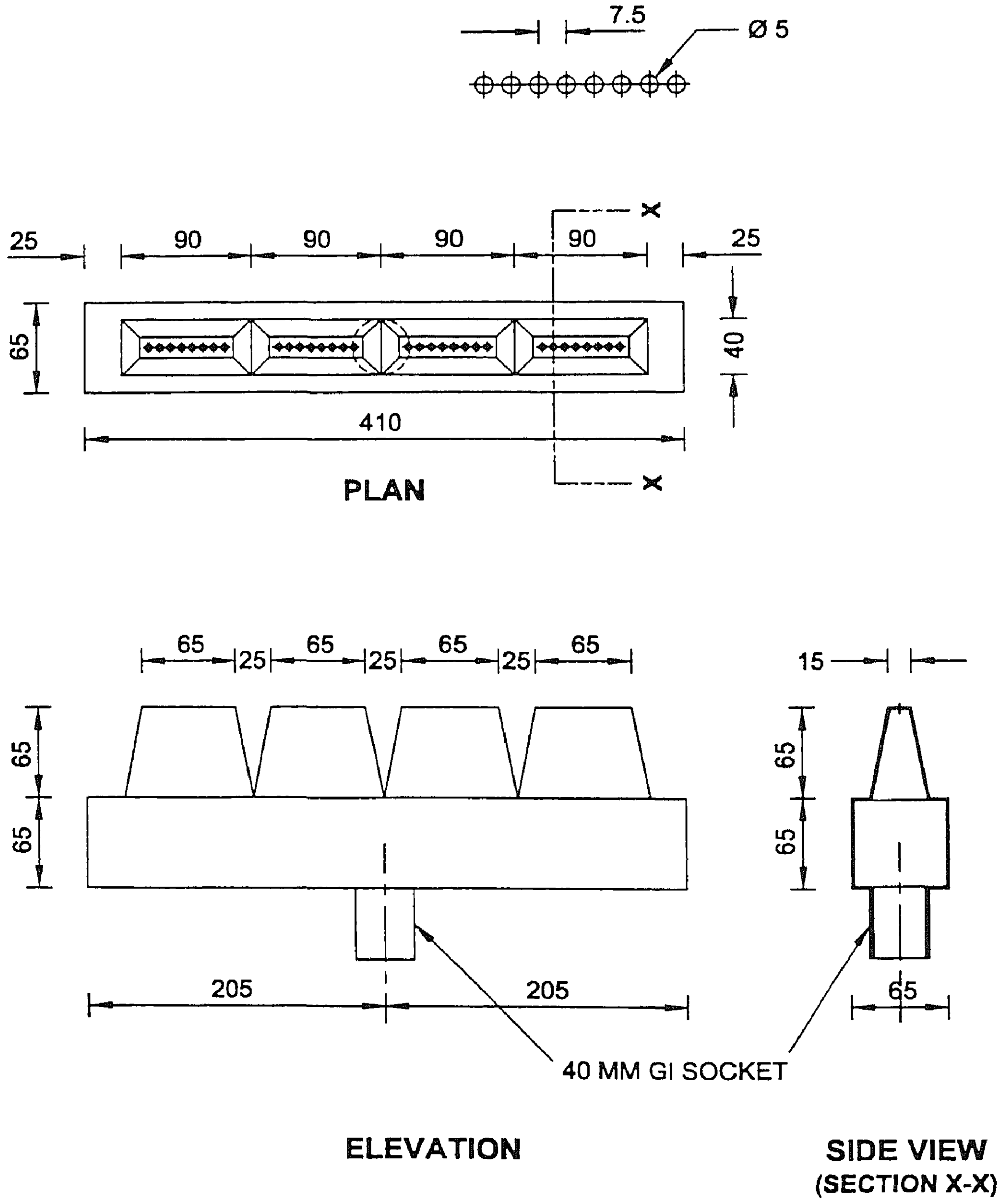
ELEVATION
(SECTION X-X)



SIDE VIEW

NOTES
1. All DIMENSIONS ARE IN MM
2 MATERIAL 2 MM MS SHEET
3 3" LONG 0 5" HEIGHT FINS IN STAGGERED LAYOUT ALONG FLOW DIRECTION IN GAS AND INNER AIR PATH

TATA ENERGY RESEARCH INSTITUTE (TERI), HABITAT PLACE, LODHI ROAD, NEW DELHI - 3			
MAIN TITLE GASIFIER BASED ITALIAN COTTAGE BASIN OVEN			
SUB TITLE HEAT EXCHANGER (AIR HEATER USING FLUE GAS WASTE HEAT)			
DRG NO TERI/BETA/2001BE42/HE-01		SCALE	REV NO 01
DATE	DRAWN BY	CHECKED BY	APPROVED BY



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1 All DIMENSIONS ARE IN MM
2 MATERIAL 2 MM MS SHEET

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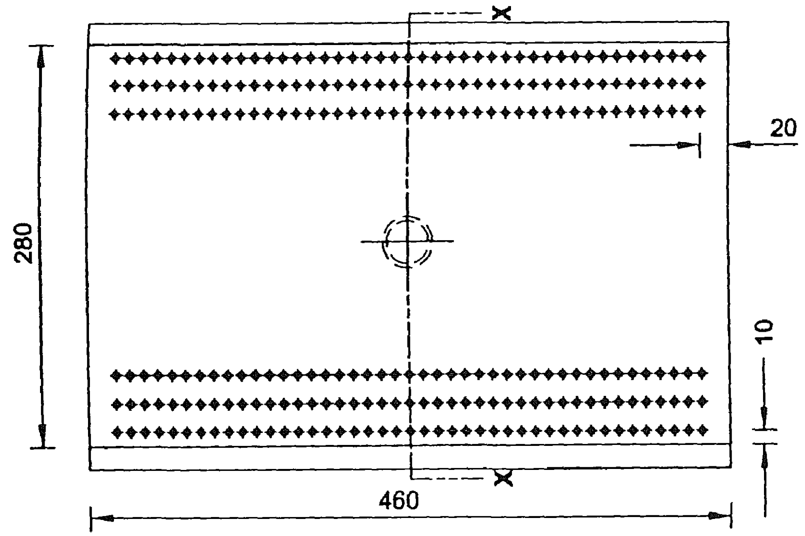
MAIN TITLE **GASIFIER BASED ITALIAN COTTAGE BASIN OVEN**			
SUB TITLE **SYSTEM FOR SILK YARN DRYING** **(HOT AIR SPRAY ARRANGEMENT)**			
DRG NO TERI/BETA/2001BE42/HTAIR-01	**SCALE**		**REV NO** 01
DATE	**DRAWN BY**	**CHECKED BY**	**APPROVED BY**



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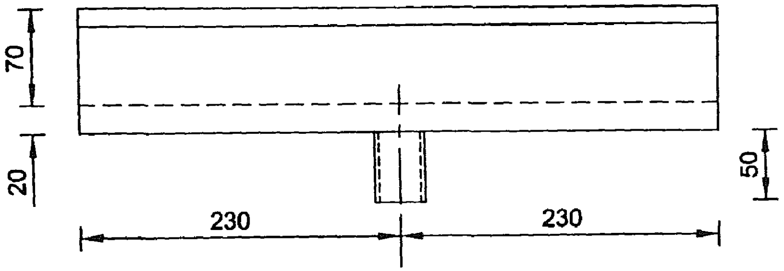

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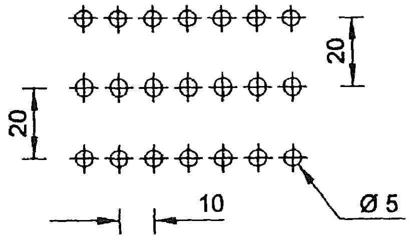

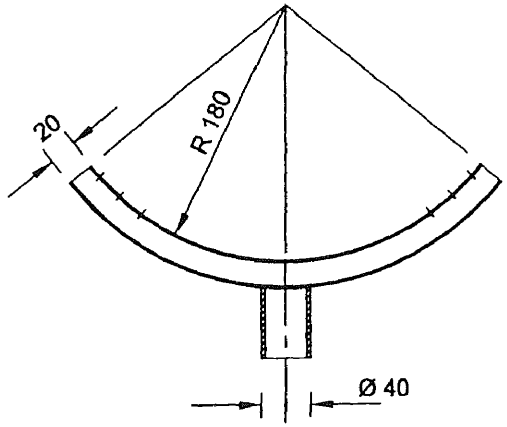

SIDE VIEW
(SECTION X-X)

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1 All DIMENSIONS ARE IN MM
2. MATERIAL 2 MM MS SHEET

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SUB TITLE SYSTEM FOR SILK YARN DRYING (HOT AIR ANNULAR PLATE ARRANGEMENT)			
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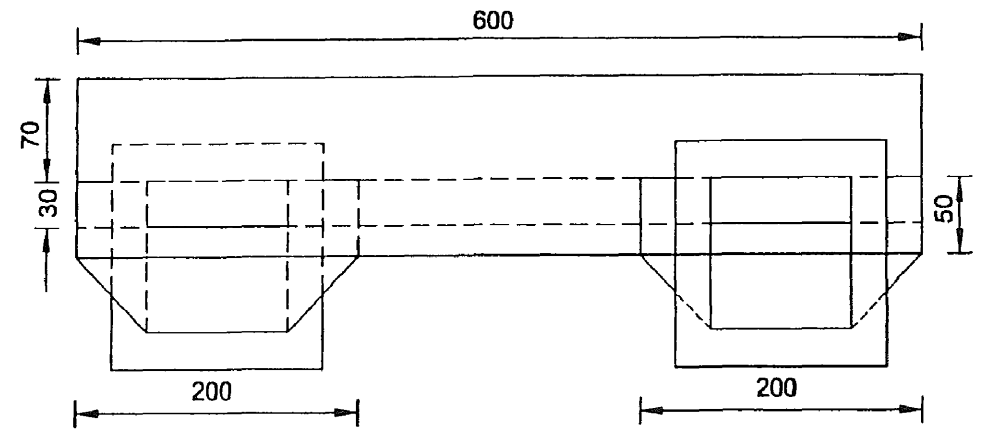

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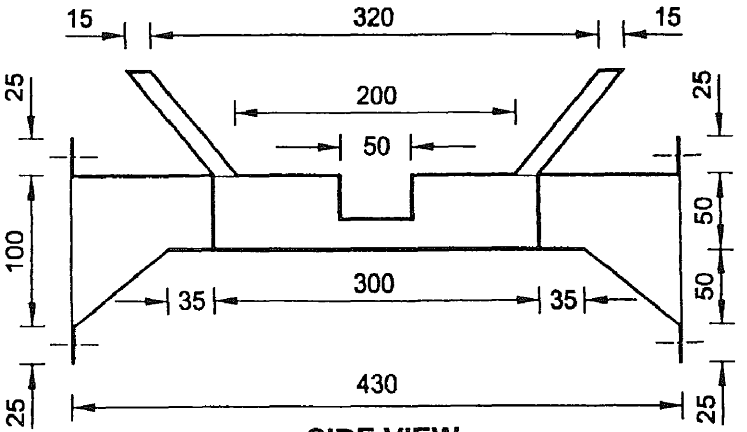
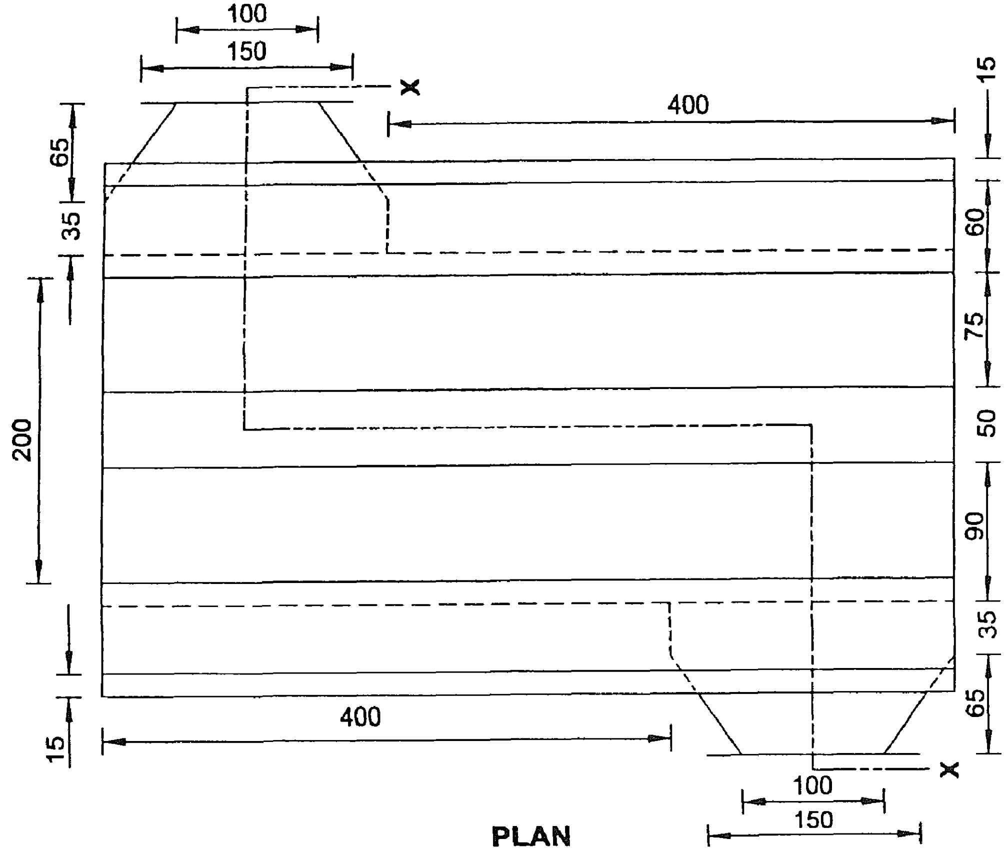


SIDE VIEW
(SECTION X-X)



PLAN

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1 All DIMENSIONS ARE IN MM
2 MATERIAL 2 MM MS SHEET

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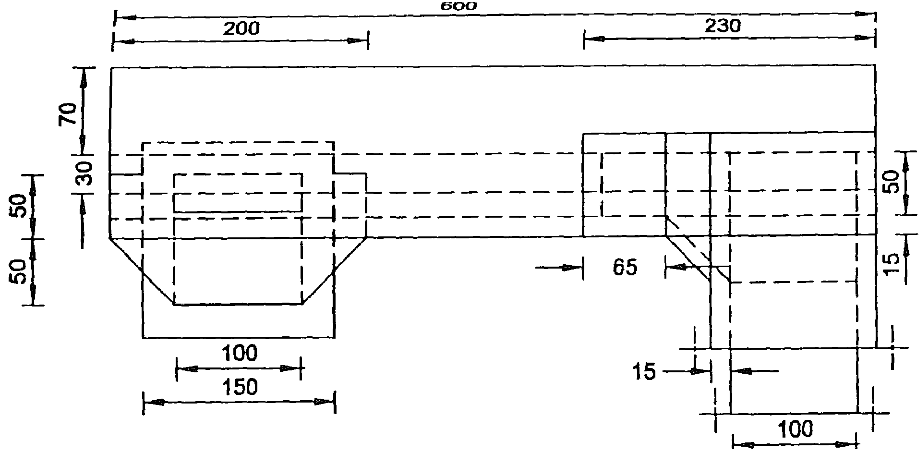
MAIN TITLE GASIFIER BASED ITALIAN COTTAGE BASIN OVEN			
SUB TITLE SYSTEM FOR SILK YARN DRYING (HOT PLATE ARRANGEMENT)			
DRG NO TERI/BETA/2001BE42/HTPLT-01		SCALE	REV NO 01
DATE	DRAWN BY	CHECKED BY	APPROVED BY



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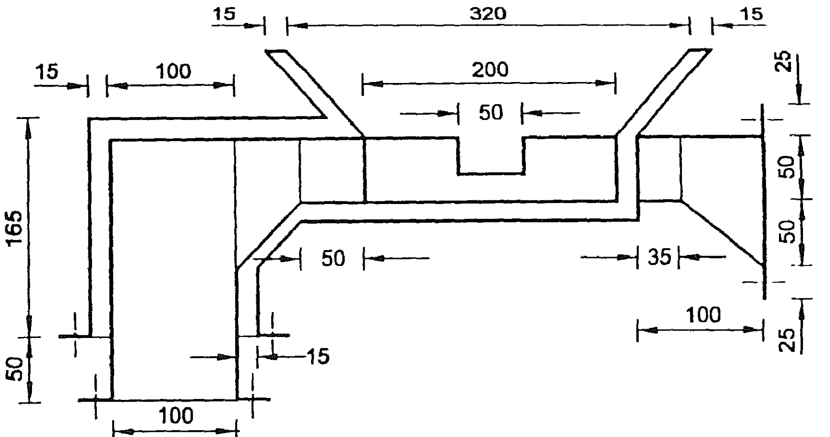
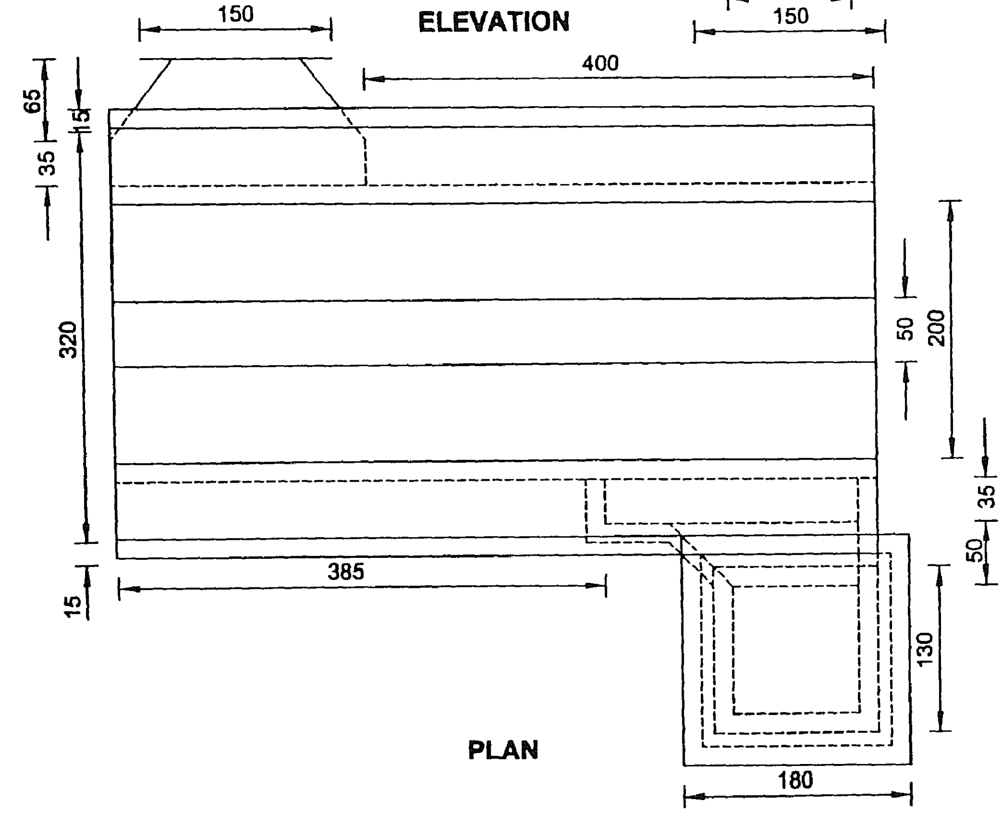


SIDE VIEW
(SECTION X-X)



PLAN

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1 All DIMENSIONS ARE IN MM
2. MATERIAL 2 MM MS SHEET

TATA ENERGY RESEARCH INSTITUTE (TERI), HABITAT PLACE, LODHI ROAD, NEW DELHI - 3			
MAIN TITLE GASIFIER BASED ITALIAN COTTAGE BASIN OVEN			
SUB TITLE SYSTEM FOR SILK YARN DRYING (COMBINED HOT PLATE + HOT AIR ARRANGEMENT)			
DRG NO TERI/BETA/2001BE42/C HP+A-01		SCALE	REV NO 01
DATE	DRAWN BY	CHECKED BY	APPROVED BY

ANNEXURE 3

Comparative field performance data collected on conventional and gasifier based Italian oven

Mr Anantha Padmanabha unit (Conventional Italian oven)

Date	Operation Time (minute)	Cook ing Time (minute)	Cocoon Processed (kg)	Silk Produced (kg)	Wood Consumption (kg)	Renditta	Wood Burning Rate (kg/hr)	Cocoon Processing Rate (kg/hr)	Silk Production rate (kg/hr)
01.4.2002	430	390	10.35	1.59	20.0	6.509	2.791	1.592	0.245
02.4.2002	685	600	16.10	2.67	31.0	6.030	2.715	1.610	0.267
03.4.2002	480	400	10.00	1.60	25.0	6.250	3.125	1.500	0.240
04.4.2002	670	590	14.47	2.50	37.0	5.788	3.313	1.472	0.254
07.4.2002	465	385	8.35	1.05	29.0	7.990	3.742	1.301	0.163
09.4.2002	670	545	10.50	1.51	38.5	6.944	3.448	1.156	0.166
10.4.2002	710	575	11.40	1.58	36.0	7.224	3.042	1.190	0.165
11.4.2002	695	595	11.25	1.62	35.5	6.944	3.065	1.134	0.163
12.4.2002	670	580	11.40	1.62	30.0	7.059	2.687	1.179	0.167
17.4.2002	690	575	8.40	1.48	40.0	5.695	3.478	0.877	0.154
18.4.2002	480	385	5.18	0.93	27.0	5.570	3.375	0.807	0.145
22.4.2002	675	530	7.50	1.53	34.0	4.918	3.022	0.849	0.173
23.4.2002	690	580	6.50	1.61	34.0	4.050	2.957	0.672	0.166
24.4.2002	690	565	5.90	1.46	34.0	4.041	2.957	0.627	0.155
26.4.2002	485	395	3.75	0.92	27.0	4.076	3.340	0.570	0.140
Average	**612**	**513**	**9.40**	**1.58**	**31.9**	**5.939**	**3.137**	**1.102**	**0.184**

Mr Anantha Padmanabha unit (Gasifier based Italian oven)

Date	Operation Time (minute)	Cook ing Time (minute)	Cocoon Processed (kg)	Silk Produced (kg)	Wood Consumption (kg)	Renditta	Wood Burning Rate (kg/hr)	Cocoon Processing Rate (kg/hr)	Silk Production rate (kg/hr)
01.4.2002	450	360	12.80	2.01	13.50	6.368	1.800	2.133	0.335
02.4.2002	680	590	13.18	2.23	19.75	5.910	1.743	1.340	0.227
03.4.2002	495	410	8.95	1.53	14.00	5.850	1.697	1.310	0.224
04.4.2002	670	590	13.95	2.43	21.50	5.753	1.925	1.419	0.247
07.4.2002	525	385	7.60	0.98	16.00	7.787	1.829	1.184	0.152
09.4.2002	670	545	10.95	1.62	21.75	6.759	1.948	1.206	0.178
10.4.2002	710	575	10.93	1.60	23.25	6.850	1.965	1.140	0.166
11.4.2002	695	590	11.07	1.64	22.25	6.771	1.921	1.126	0.166
12.4.2002	695	580	11.40	1.63	22.50	7.015	1.942	1.179	0.168
17.4.2002	700	575	8.30	1.49	22.50	5.563	1.929	0.866	0.156
18.4.2002	480	385	5.32	0.96	16.75	5.542	2.094	0.829	0.150
22.4.2002	665	530	7.50	1.57	21.25	4.777	1.917	0.849	0.178
23.4.2002	680	580	6.60	1.62	23.50	4.074	2.074	0.683	0.168
24.4.2002	700	560	5.80	1.47	24.40	3.946	2.091	0.621	0.158
26.4.2002	490	395	3.88	0.99	16.50	3.919	2.020	0.589	0.150
Average	**620**	**510**	**9.22**	**1.58**	**19.96**	**5.792**	**1.926**	**1.098**	**0.188**

Mr B M Gurumurthy unit (Conventional Italian oven)

Date	Operation Time (minute)	Cook ing Time (minute)	Cocoon Processed (kg)	Silk Produced (kg)	Wood Consumption (kg)	Renditta	Wood Burning Rate (kg/hr)	Cocoon Processing Rate (kg/hr)	Silk Production rate (kg/hr)
01.02.2002	665	540	12.4	1.97	40	6.294	3.609	1.378	0.219
06.02.2002	665	580	11.85	2.05	42	5.780	3.789	1.226	0.212
07.02.2002	665	555	10.7	2.02	38	5.297	3.429	1.157	0.218
08.02.2002	660	545	12.605	2.07	34	6.089	3.091	1.388	0.228
12.02.2002	630	550	11.3	2.025	43	5.580	4.095	1.233	0.221
13.02.2002	660	560	10.58	1.89	45	5.598	4.091	1.134	0.203
14.02.2002	650	570	10.51	1.93	45	5.446	4.154	1.106	0.203
15.02.2002	660	565	10.44	1.93	48	5.409	4.364	1.109	0.205
16.02.2002	670	530	10.48	1.915	42	5.473	3.761	1.186	0.217
19.02.2002	615	560	10.89	1.84	42	5.918	4.098	1.167	0.197
20.02.2002	660	535	12.21	1.83	37	6.672	3.364	1.369	0.205
21.02.2002	820	735	13.72	2.18	46.5	6.294	3.402	1.120	0.178
22.02.2002	615	550	10.75	1.75	35	6.143	3.415	1.173	0.191
26.02.2002	855	740	14.02	2.4	47.5	5.842	3.333	1.137	0.195
29.03.2002	445	385	4.45	1.095	26	4.064	3.506	0.694	0.171
30.03.2002	615	560	7.85	1.89	32	4.153	3.122	0.841	0.203
01.04.2002	635	565	9.02	2.07	31	4.357	2.929	0.958	0.220
02.04.2002	640	560	11.45	2.07	34	5.531	3.188	1.227	0.222
03.04.2002	815	730	13.54	2.53	40.39	5.352	2.973	1.113	0.208
04.04.2002	635	555	9.25	2.01	32.9	4.602	3.109	1.000	0.217
05.04.2002	630	550	9.25	2.02	34	4.579	3.238	1.009	0.220
10.04.2002	790	725	13.09	2.73	33	4.795	2.506	1.083	0.226
11.04.2002	810	735	11.83	2.525	36	4.685	2.667	0.966	0.206

Date	Operation Time (minute)	Cook ing Time (minute)	Cocoon Processed (kg)	Silk Produced (kg)	Wood Consumption (kg)	Renditta	Wood Burning Rate (kg/hr)	Cocoon Processing Rate (kg/hr)	Silk Production rate (kg/hr)
12.04.2002	615	560	9	2.03	31	4.433	3 024	0 964	0.218
16.04.2002	620	560	7.98	2.165	33 5	3.686	3.242	0.855	0.232
19.04.2002	820	750	11.93	2.54	39	4 697	2 854	0.954	0.203
24.04.2002	650	585	5.97	1 945	28.03	3.069	2.587	0.612	0.199
25.04.2002	625	735	8.24	2.395	45	3.441	4.320	0.673	0.196
26.04.2002	625	555	5 67	1 855	31.5	3.057	3 024	0.613	0.201
27.04.2002	605	550	5.63	1.79	33	3.145	3.273	0 614	0.195
03 05.2002	610	555	6.25	1.885	34	3 316	3 344	0.676	0.204
04 05.2002	625	560	6.35	1 855	34	3.423	3.264	0.680	0.199
07.05.2002	615	540	7.43	1 65	33	4.503	3.220	0.826	0.183
08.05.2002	620	545	7.78	1 65	38	4.715	3 677	0 857	0.182
09 05.2002	670	545	8.68	1.79	37	4 849	3.313	0.956	0.197
11.05.2002	420	360	5.63	1.26	20	4 468	2 857	0.938	0.210
Average	**656**	**580**	**9.687**	**1.988**	**36.703**	**4.854**	**3.368**	**1.000**	**0.206**

Mr B M Gurumurthy unit (Gasifier based Italian oven)

Date	Operation Time (minute)	Cook ing Time (minute)	Cocoon Processed (kg)	Silk Produced (kg)	Wood Consumption (kg)	Renditta	Wood Burning Rate (kg/hr)	Cocoon Processing Rate (kg/hr)	Silk Production rate (kg/hr)
01.02.2002	675	540	11 72	1 82	29	6.440	2.578	1 302	0 202
06.02.2002	665	580	11.05	1 95	30	5 667	2.707	1.143	0 202
07.02.2002	680	555	10.8	2 05	25 5	5 268	2.250	1.168	0 222
08.02.2002	680	545	11 95	2	25	5 975	2.206	1.316	0.220
12 02.2002	675	550	11.17	1.97	29 5	5 670	2 622	1.219	0 215
13.02.2002	675	565	10.12	1.84	27.5	5 500	2.444	1 075	0 195
14.02.2002	680	595	9.69	1 79	28.5	5 413	2 515	0 977	0 181
15.02.2002	685	575	10.35	1 94	28.5	5 335	2.496	1.080	0 202
16.02.2002	695	530	9.99	1 835	28	5.444	2.417	1.131	0 208
19.02.2002	615	560	10.92	1.92	26	5 688	2.537	1.170	0.206
20.02.2002	660	535	11.82	1.84	25.6	6.424	2.327	1.326	0 206
21.02.2002	820	735	15.12	2.47	30	6.121	2.195	1.234	0.202
22.02.2002	605	550	10.76	1.79	24.7	6.011	2 450	1.174	0.195
26.02.2002	855	740	14.19	2.39	30	5.937	2.105	1.151	0.194
29.3.2002	445	385	4 615	1.14	17	4 048	2.292	0.719	0.178
30.3.2002	620	560	7 72	1.85	23.75	4.173	2.298	0.827	0.198
01.04.2002	630	565	8.82	1.85	22.5	4.768	2.143	0.937	0.196
02.04.2002	660	560	10.65	1.88	24	5 665	2.182	1.141	0.201
03.04.2002	830	730	12.25	2.339	31	5.237	2.241	1 007	0 192
04.04.2002	645	555	8.86	1.88	24	4.713	2.233	0 958	0.203
05.04.2002	630	550	8.567	1.927	24	4.446	2.286	0.935	0.210
10.04.2002	790	725	11.78	2.493	30	4.725	2.278	0.975	0.206
11.04.2002	810	735	10.11	2.14	29	4.724	2.148	0.825	0.175

Date	Operation Time (minute)	Cook ing Time (minute)	Cocoon Processed (kg)	Silk Produced (kg)	Wood Consumption (kg)	Renditta	Wood Burning Rate (kg/hr)	Cocoon Processing Rate (kg/hr)	Silk Production rate (kg/hr)
12.04.2002	620	560	8.4	1.867	23.5	4.499	2.274	0.900	0.200
16.04.2002	610	560	6.76	1.867	22.5	3.621	2.213	0.724	0.200
19.04.2002	825	750	11.16	2.42	29.5	4.612	2.145	0.893	0.194
24.04.2002	660	595	6.14	1.99	23.75	3.085	2.159	0.619	0.201
24 04.2002	835	735	7.8	2.45	29.75	3.184	2.138	0.637	0.200
26.04.2002	635	555	6.18	2.04	23.5	3.029	2.220	0.668	0.221
27.04.2002	605	550	5.92	1.92	22.75	3.083	2.256	0.646	0.209
03.05.2002	600	555	5.813	1.78	23	3.266	2.300	0.628	0.192
04.05.2002	625	560	5.853	1.806	23	3.241	2.208	0.627	0.194
07.05.2002	620	545	7	1.61	22	4.348	2.129	0.771	0.177
08.05.2002	620	555	7.6	1.665	20	4.565	1.935	0.822	0.180
09.05.2002	690	545	8.3	1 81	22.5	4.586	1.957	0.914	0.199
11.05.2002	420	360	4.93	1.125	14.5	4.382	2.071	0.822	0.188
Average	**669**	**582**	**9.302**	**1.929**	**25.369**	**4.803**	**2.277**	**0.957**	**0.199**

Mr Anantha Padmanabha unit

Date	Specific fuel consumption (kg per kg cocoon)		Fuelwood saving (%)		Renditta Improvement	Increase in silk yield (%)
	Conventional	Gasifier	kg/kg cocoon basis	kg/hr basis		
01.04.2002	1 932	1.055	45.420	35.500	0.141	2.218
02.04.2002	1.925	1.498	22.176	35.822	0.120	2.024
03.04 2002	2.500	1.564	37.430	45.697	0.400	6.844
04.04 2002	2.557	1 541	39.726	41.892	0.035	0.616
07.04.2002	3.473	2.105	39.383	51.133	0.204	2.614
09.04.2002	3.667	1.986	45.828	43.506	0.185	2.740
10.04 2002	3.158	2.128	32.609	35.417	0.375	5.472
11.04.2002	3.156	2.010	36.305	37.324	0.174	2.567
12.04.2002	2.632	1.974	25.000	27.698	0.043	0.619
17.04 2002	4.762	2.711	43.072	44.554	0.132	2.371
18.04 2002	5.212	3.148	39.596	37.963	0.028	0.509
22.04.2002	4.533	2.833	37.500	36.560	0.141	2.951
23.04 2002	5.231	3.561	31.930	29.866	-0.024	-0.595
24.04.2002	5.763	4.207	26.998	29.261	0.096	2.421
26.04.2002	7.200	4.253	35.927	38.014	0.157	4.003
Average	3.847	2.438	35.927	38.014	0.147	2.492
STD Dev	1.545	0.985	7.067	6.486	0.117	1.912

Mr B M Gurumurthy unit

Date	Specific fuel consumption (kg per kg cocoon)		Fuelwood saving (%)		Renditta Improvement	Increase in silk yield (%)
	Conventional	Gasifier	kg/kg cocoon basis	kg/hr basis		
01.02.2002	3.226	2.474	23.294	28.574	-0.145	-2.254
06.02 2002	3.544	2.715	23.400	28.571	0.114	2.009
07.02.2002	3.551	2.361	33.516	34.375	0.029	0.545
08.02.2002	2.697	2.092	22.440	28.633	0 114	1.914
12.02.2002	3.805	2.641	30.597	35.969	-0.090	-1.584
13.02.2002	4.253	2.717	36.111	40.247	0.098	1.780
14.02.2002	4.282	2.941	31.307	39.461	0.032	0.595
15.02.2002	4.598	2.754	40.109	42.792	0.074	1.392
16.02.2002	4.008	2.803	30.063	35.731	0.028	0.522
19.02.2002	3.857	2.381	38.265	38.095	0.231	4.061
20 02.2002	3.030	2.166	28.528	30.811	0.248	3.864
21.02.2002	3.389	1.984	41.458	35.484	0.172	2.812
22.02.2002	3.256	2.296	29.494	28.262	0.132	2.191
26.02.2002	3.388	2.114	37.599	36.842	-0 096	-1.610
29.03.2002	5.843	3.684	36.953	34.615	0.016	0.387
30.03.2002	4.076	3.076	24.531	26.380	-0.020	-0.468
01.04.2002	3.437	2.551	25.774	26.843	-0.410	-8.601
02.04 2002	2.969	2.254	24.109	31.551	-0.133	-2.356
03.04.2002	2.983	2.531	15 166	24.635	0 114	2.186
04.04.2002	3.557	2.709	23.841	28 183	-0.111	-2.351
05.04 2002	3.676	2.801	23.784	29.412	0.133	3.001
10.04.2002	2.521	2.547	-1.019	9.091	0.070	1.474
11 04.2002	3.043	2.868	5.740	19.444	-0.039	-0.829
12.04.2002	3.444	2.798	18.779	24.805	-0 066	-1.460
16.04.2002	4.198	3.328	20.714	31.735	0.065	1.799
19.04.2002	3.269	2.643	19.140	24.817	0.085	1.849
24.04.2002	4.695	3.868	17.615	16.553	-0.016	-0.519
25.04.2002	5.461	3.814	30.160	50.516	0.257	8.067
26.04.2002	5.556	3.803	31.553	26.572	0.027	0.898
27.04.2002	5.861	3.843	34.438	31.061	0.062	2.008
03.05.2002	5.440	3.957	27.267	31.225	0.050	1.529
04.05.2002	5.354	3.930	26.609	32.353	0.182	5.626
07.05.2002	4.441	3.143	29.238	33.871	0.155	3.570
08.05 2002	4.884	2.632	46.122	47.368	0.151	3.299
09.05.2002	4.263	2.711	36.405	40.952	0.264	5.747
11.05.2002	3.552	2.941	17.206	27.500	0 086	1.963
Average	3.984	2.857	27.231	31.481	0.052	1.196
Std Dev	0.914	0.572	9.638	8.050	0.134	2.889

ANNEXURE 4

Comparative charcoal consumption data collected on hot plate and hot air system

Comparison of charcoal consumption: Gurumurthy unit

Date	Charcoal consumption (gm/RB/day)				Charcoal saving (gm/RB/day)	
	Traditional system		Gasifier system			
	RB-1	RB-2	Hot plate	Hot air	Hot plate	Hot air
01-Feb-02	1035	1060	180	180	855	880
06-Feb-02	1140	1050	195	130	945	920
07-Feb-02	980	1150	220	250	760	900
08-Feb-02	1240	1260	430	425	810	835
12-Feb-02	1050	1010	330	300	720	710
13-Feb-02	1055	1220	275	190	780	1030
14-Feb-02	710	690	150	180	560	510
15-Feb-02	880	710	150	180	730	530
16-Feb-02	685	650	150	180	535	470
19-Feb-02	770	725	295	375	475	350
20-Feb-02	815	1185	300	300	515	885
21-Feb-02	1325	1175	370	330	955	845
22-Feb-02	1685	1235	870	480	815	755
26-Feb-02	1370	1370	230	360	1140	1010
Average	1052.86	1035 00	296.07	275.71	756.79	759.29
Std Dev	283.09	242.24	186 52	107.77	189.30	213.68
Average percentage charcoal saving (%)					71.88	73.36

ANNEXURE 5

Cost benefit analysis for various configurations

Case-1: Basic gasifier model, charcoal outsourced

Case-2: Basic gasifier model, charcoal from gasifier

Case-3: Basic gasifier model and hot air system

Case-4: Basic gasifier model and combined hot plate-hot air

Case-1: Basic gasifier model, charcoal outsourced

Parameter	Gurumurthy		Anantha Padmanabha	
	Conventional	Gasifier	Conventional	Gasifier
Cocoon processed (kg)	20		20	
Average renditta (kg cocoon/kg silk)	4.854	4.803	5.939	5.792
Silk produced (kg)	4.120	4.164	3.368	3.453
Specific fuel consumption (kg/kg cocoon)	3.984	2.857	3.847	2.438
Fuelwood consumed (kg)	79.680	57.140	76.940	48.760
Charcoal consumed (kg)	0.0	4.0	0.0	4.0
Kerosene consumed (kg)	0.0	0.4	0.0	0.4
Fuelwood price (Rs)	1.40		1.40	
Charcoal price (Rs)	4.00		4 00	
Kerosene price (Rs)	18.00		18.00	
Cost of fuelwood (Rs)	111.55	80.00	107.72	68.26
Cost of charcoal (Rs)	0.00	16.00	0.00	16.00
Cost of kerosene (Rs)	0.00	7.20	0.00	7.20
Total fuel cost (Rs)	111.55	103.20	107.72	91.46
Additional silk produces (kg)	0.000	0.044	0.00	0.085
Silk price (Rs/kg)	1450		1450	
Daily fuel saving (Rs)	8.36		16.25	
Additional daily income through increased silk production (Rs)	63.44		123.93	
Total daily benefits (Rs)	71.79		140.18	

Case-2: Basic gasifier model, charcoal from gasifier

Parameter	Gurumurthy		Anantha Padmanabha	
	Conventional	Gasifier	Conventional	Gasifier
Cocoon processed (kg)	20		20	
Average renditta (kg cocoon/kg silk)	4.854	4.803	5.939	5.792
Silk produced (kg)	4.120	4.164	3.368	3.453
Specific fuel consumption (kg/kg cocoon)	3.984	2.857	3.847	2.438
Fuelwood consumed (kg)	79.680	69.140	76.940	60.760
Charcoal consumed (kg)	0.0	0.0	0.0	0.0
Kerosene consumed (kg)	0.0	0.4	0.0	0.4
Fuelwood price (Rs)	1.40		1.40	
Charcoal price (Rs)	4.00		4.00	
Kerosene price (Rs)	18.00		18.00	
Cost of fuelwood (Rs)	111.55	96.80	107.72	85.06
Cost of charcoal (Rs)	0.00	0.00	0.00	0.00
Cost of kerosene (Rs)	0.00	7.20	0.00	7.20
Total fuel cost (Rs)	111.55	104.00	107.72	93.26
Additional silk produces (kg)	0.000	0.044	0.00	0.085
Silk price (Rs/kg)	1450		1450	
Daily fuel saving (Rs)	7.56		15.45	
Additional daily income through increased silk production (Rs)	63.44		123.93	
Total daily benefits (Rs)	70.99		139.38	

Case-3: Basic gasifier model and hot air system

Parameter	Gurumurthy		Anantha Padmanabha	
	Conventional	Gasifier	Conventional	Gasifier
Cocoon processed (kg)	20		20	
Average renditta (kg cocoon/kg silk)	4.854	4.803	5.939	5.792
Silk produced (kg)	4.120	4.164	3.368	3.453
Specific fuel consumption (kg/kg cocoon)	3.984	2.857	3.847	2.438
Fuelwood consumed (kg)	79.680	57 140	76.940	48.760
Charcoal consumed (kg)	0.0	1.104	0.0	1.104
Kerosene consumed (kg)	0.0	0.8	0.0	0.8
Fuelwood price (Rs)	1.40		1.40	
Charcoal price (Rs)	4.00		4.00	
Kerosene price (Rs)	18.00		18.00	
Cost of fuelwood (Rs)	111.55	80.00	107.72	68.26
Cost of charcoal (Rs)	0.00	4.42	0.00	4.42
Cost of kerosene (Rs)	0.00	14.40	0.00	14.40
Total fuel cost (Rs)	111.55	98.81	107.72	87.08
Additional silk produces (kg)	0.000	0.044	0.00	0.085
Silk price (Rs/kg)	1450		1450	
Daily fuel saving (Rs)	12.74		20.64	
Additional daily income through increased silk production (Rs)	63.44		123.93	
Total daily benefits (Rs)	76.18		144.57	

Case-4: Basic gasifier model and combined hot plate-hot air

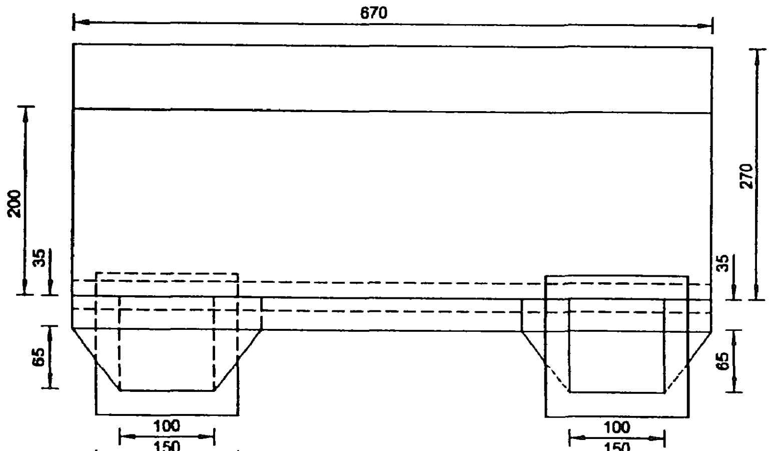
Parameter	Gurumurthy		Anantha Padmanabha	
	Conventional	Gasifier	Conventional	Gasifier
Cocoon processed (kg)	20		20	
Average renditta (kg cocoon/kg silk)	4.854	4.803	5.939	5.792
Silk produced (kg)	4 120	4.164	3 368	3.453
Specific fuel consumption (kg/kg cocoon)	3.984	2.857	3.847	2.438
Fuelwood consumed (kg)	79.680	57 140	76.940	48.760
Charcoal consumed (kg)	0.0	1.184	0.0	1.184
Kerosene consumed (kg)	0.0	0.4	0.0	0.4
Fuelwood price (Rs)	1.40		1.40	
Charcoal price (Rs)	4.00		4.00	
Kerosene price (Rs)	18.00		18.00	
Cost of fuelwood (Rs)	111.55	80.00	107.72	68.26
Cost of charcoal (Rs)	0.00	4.74	0.00	4.74
Cost of kerosene (Rs)	0.00	7.20	0.00	7.20
Total fuel cost (Rs)	111.55	91.93	107.72	80.20
Additional silk produces (kg)	0.000	0.044	0.00	0.085
Silk price (Rs/kg)	1450		1450	
Daily fuel saving (Rs)	19.62		27.52	
Additional daily income through increased silk production (Rs)	63.44		123.93	
Total daily benefits (Rs)	83.06		151.45	

ANNEXURE 6

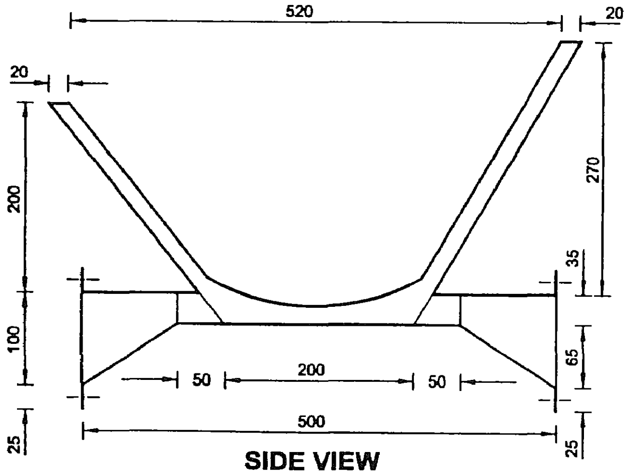
Detailed Technical Drawings of Improved Charka Oven

a. Silk yarn drying system (Hot plate using flue gas waste heat)
Drawing No TERI/BETA/2001BE42/CHARKA-01

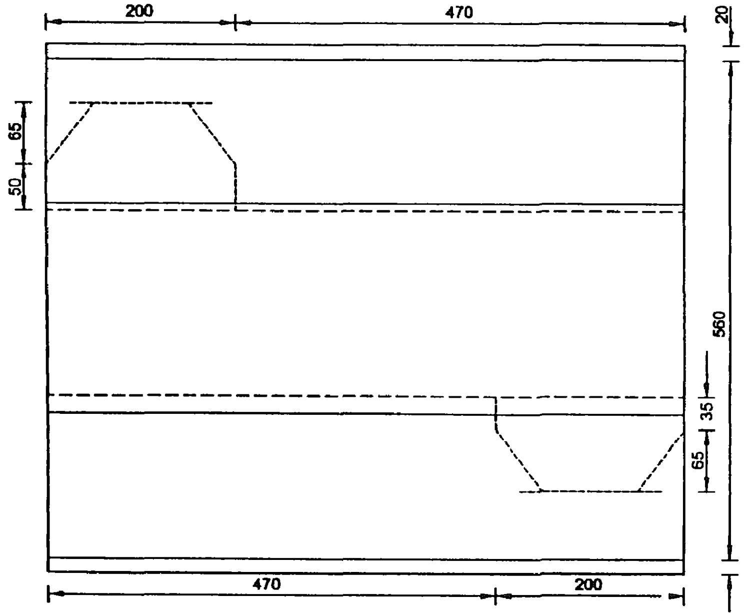
b. Heat exchanger for water preheating (For flue gas waste heat recovery)
Drawing No TERI/BETA/2001BE42/CHARKA-02



ELEVATION

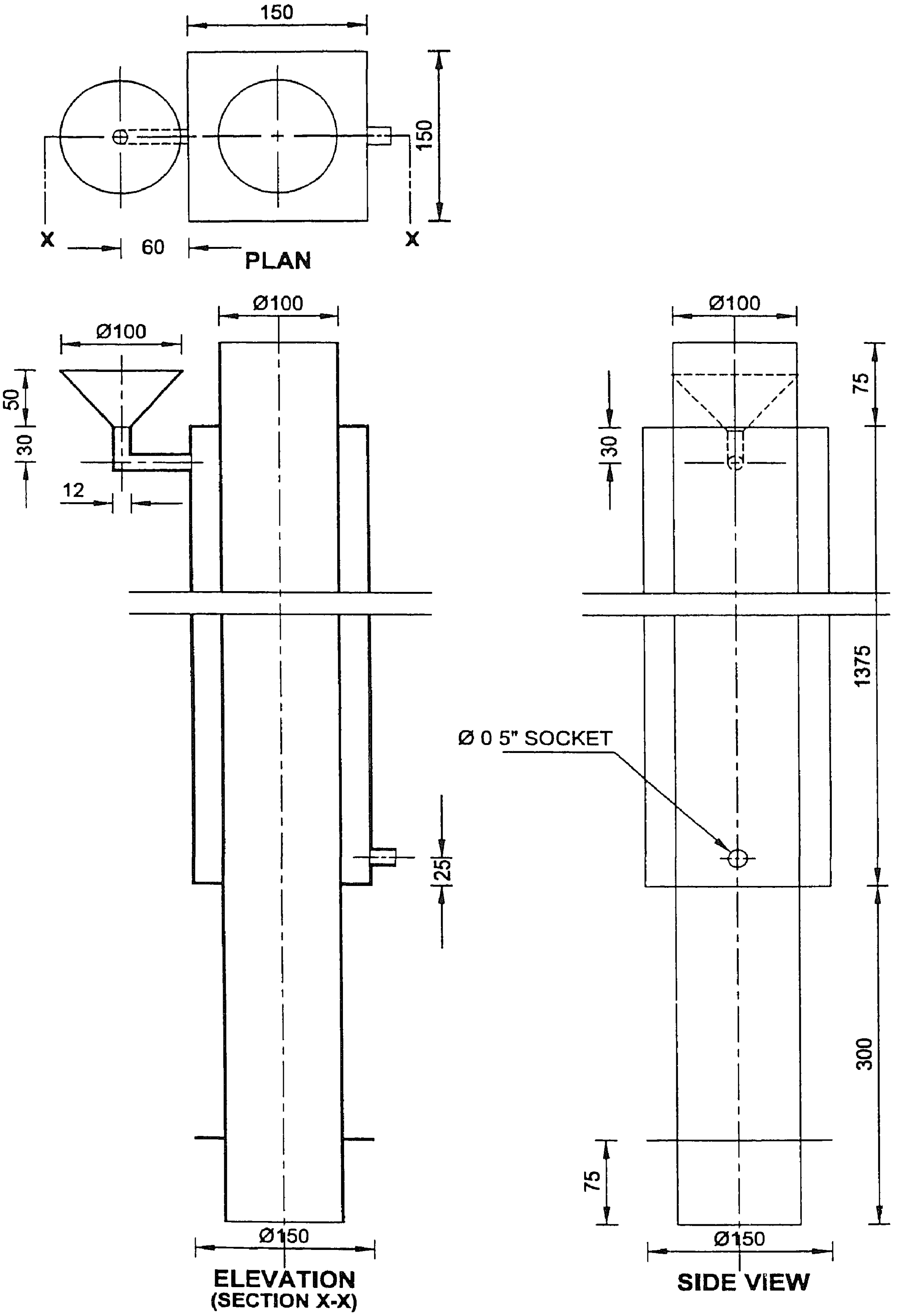


SIDE VIEW
(SECTION X-X)



PLAN

TATA ENERGY RESEARCH INSTITUTE (TERI), **HABITAT PLACE, LODHI ROAD, NEW DELHI - 3**			
MAIN TITLE	IMPROVED CHARKA OVEN		
SUB TITLE	SILK YARN DRYING SYSTEM (HOT PLATE USING FLUE GAS WASTE HEAT)		
DRG NO TERI/BETA/2001BE42/CHARKA-1		SCALE	REV NO 01
DATE	DRAWN BY	CHECKED BY	APPROVED BY



TATA ENERGY RESEARCH INSTITUTE (TERI),
HABITAT PLACE, LODHI ROAD, NEW DELHI - 3

MAIN TITLE IMPROVED CHARKA OVEN

SUB TITLE HEAT EXCHANGER FOR WATER PREHEATING
(FOR FLUE GAS WASTE HEAT RECOVERY)

DRG NO TERI/BETA/2001BE42/CHARKA-2		SCALE	REV NO 01
DATE	DRAWN BY	CHECKED BY	APPROVED B